Percutaneous Coronary Intervention, Repatriation and Unplanned Readmissions: Characteristics of percutaneous coronary intervention patients who experience an unplanned readmission after repatriation from a tertiary hospital

A thesis presented in partial fulfilment of the requirements for the degree of Master of Nursing at the Eastern Institute of Technology Taradale, New Zealand

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2009
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Abstract

Background
The use of air ambulances to transport cardiac patients has grown rapidly over the past decade in New Zealand. There were in excess of 3000 fixed wing air ambulance missions flown in 2005. Both pressurized and unpressurized air ambulances are used. The altitude exposure guidelines for safe transport of people with heart disease were developed 50 years ago. These guidelines do not meet best practice standards and there is little research into transportation of acutely unwell or post interventional cardiac patients in the aeromedical environment. In the New Zealand context there are no consistent guidelines between the various aeromedical services for the transportation of cardiac patients in air ambulances.

Objective
The objective was to describe the demographic and clinical characteristics of patients who have an unplanned readmission to a regional hospital after undergoing percutaneous coronary angioplasty at a tertiary hospital.

Methodology and design
A cohort study design of patients repatriated using different transport types was undertaken using observational data from admission episode information, and international classification of diseases codes. The data were extracted from the National Minimum Dataset and from a regional hospital’s patient transport database. Sixteen thousand eight hundred and fifty patient records were included in the study comprising of 18,577 index admissions. Five hundred and fifty-six patients were in the cohort of readmissions after repatriation to the regional hospital.
Findings

Patients who were transported by commercial aircraft have a significantly lower incidence of unplanned readmission than patients who were transported by air ambulance. However, there is no statistical difference in unplanned readmission rates when comparing the use of unpressurized air ambulance to pressurized air ambulance transportation. Patients who undergo percutaneous coronary intervention are at significantly lower risk of unplanned readmission than those who undergo coronary artery bypass graft surgery, or coronary angiography.

Conclusion

Unplanned readmission to hospital of patients after undergoing percutaneous coronary intervention is not influenced by the type of air ambulance used in their repatriation. The current altitude guidelines for transportation of cardiac patients appear to be safe to use in air ambulance transports of post percutaneous coronary intervention patients who have a flight time less than 90 minutes. Unplanned readmission to hospital of post percutaneous coronary intervention patients may be influenced by the close and extended monitoring of them during repatriation via air ambulance.
Figure 1 The ill-fated flight of the Zenith in 1875. (LOT 13400, no. 35, Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA)
Acknowledgements

To my supervisor, Dr Bob Marshall for guiding me through the writing of this research. The journey was challenging, but in the role of principal supervisor, you kept me focussed and gave encouragement and advice which made the journey less painful. I also thank Judy Searle my associate supervisor for her input. Both were extremely generous with their knowledge and my appreciation is heartfelt. I would also like to acknowledge the input of Dr Rachel Forrest, without whom I would have been lost in numbers. Her skills and expertise in statistical analysis saved my sanity and allowed me to complete this project on time.

Librarians rarely receive the credit they are due, but without Marianna, Marion and Viv, I would not have had access to the wealth of information which was required, papers which were 50 years old were found with a smile, books were begged, borrowed and bought so that my project had the resources it needed. For everything you have done for me over the past two years, thank you again.

To my wife Wendy who shared the journey with me and suffered my late nights, closed doors and bad grammar, and to Callum and Kane, my sons, who lost me to week-ends of writing, I owe a debt of gratitude.

“There is nothing like looking, if you want to find something. You certainly usually find something, if you look, but it is not always quite the something you were after.”

J.R.R Tolkien (1892 – 1973)
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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>Air Ambulance</td>
</tr>
<tr>
<td>ACC</td>
<td>Accident compensation corporation</td>
</tr>
<tr>
<td>ACCP</td>
<td>American College of Chest Physicians</td>
</tr>
<tr>
<td>ACS</td>
<td>Acute coronary syndrome</td>
</tr>
<tr>
<td>AMI</td>
<td>Acute myocardial infarction</td>
</tr>
<tr>
<td>AMSL</td>
<td>Above mean sea level</td>
</tr>
<tr>
<td>ASHBEAMS</td>
<td>American Society of Hospital Based Emergency Aeromedical Services</td>
</tr>
<tr>
<td>BTS</td>
<td>British Thoracic Society</td>
</tr>
<tr>
<td>CABG</td>
<td>Coronary artery bypass graft</td>
</tr>
<tr>
<td>CCU</td>
<td>Coronary care unit</td>
</tr>
<tr>
<td>CHF</td>
<td>Congestive heart failure</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>COPD</td>
<td>Chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>ED</td>
<td>Emergency Department</td>
</tr>
<tr>
<td>DHB</td>
<td>District health board</td>
</tr>
<tr>
<td>ECG</td>
<td>Electrocardiogram</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration (U.S.A.)</td>
</tr>
<tr>
<td>FL</td>
<td>Flight level (expressed as FL150 for 15,000 ft, FL200 for 20,000 ft etc.)</td>
</tr>
<tr>
<td>ft</td>
<td>Foot / Feet</td>
</tr>
<tr>
<td>HBDHB</td>
<td>Hawke’s Bay District Health Board</td>
</tr>
<tr>
<td>ICD</td>
<td>International classification of diseases</td>
</tr>
<tr>
<td>IFR</td>
<td>Instrument flight rules</td>
</tr>
<tr>
<td>ICHI</td>
<td>International classification of health interventions</td>
</tr>
<tr>
<td>IHD</td>
<td>Ischemic heart disease</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td>LNI</td>
<td>Lower North Island</td>
</tr>
<tr>
<td>NHI</td>
<td>National Health Index</td>
</tr>
<tr>
<td>NMDS</td>
<td>National Minimum Data Set</td>
</tr>
<tr>
<td>NSTEMI</td>
<td>Non-ST Segment Elevating Myocardial Infarction</td>
</tr>
<tr>
<td>NZFNA</td>
<td>New Zealand Flight Nurses Association</td>
</tr>
<tr>
<td>NZHIS</td>
<td>New Zealand Health Information Service</td>
</tr>
<tr>
<td>MS</td>
<td>Microsoft</td>
</tr>
<tr>
<td>MBS</td>
<td>Medicare benefits schedule</td>
</tr>
<tr>
<td>MI</td>
<td>Myocardial infarction</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for economic cooperation and development</td>
</tr>
<tr>
<td>O₂</td>
<td>Oxygen</td>
</tr>
<tr>
<td>PCO₂</td>
<td>Partial pressure of carbon dioxide</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>Partial arterial pressure of carbon dioxide dissolved in plasma</td>
</tr>
<tr>
<td>PaO₂</td>
<td>Partial arterial pressure of oxygen dissolved in plasma</td>
</tr>
<tr>
<td>PO₂</td>
<td>Partial pressure of oxygen</td>
</tr>
<tr>
<td>PCI</td>
<td>Percutaneous coronary intervention</td>
</tr>
<tr>
<td>psi</td>
<td>Pounds per square inch</td>
</tr>
<tr>
<td>RFDS</td>
<td>Royal Flying Doctor Service</td>
</tr>
<tr>
<td>SaO₂</td>
<td>Arterial percentage saturation of haemoglobin by oxygen</td>
</tr>
<tr>
<td>SpO₂</td>
<td>Peripheral percentage saturation of haemoglobin by oxygen</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for Social Sciences</td>
</tr>
<tr>
<td>STEMI</td>
<td>ST Segment Elevating Myocardial Infarction</td>
</tr>
<tr>
<td>UA</td>
<td>Unstable angina</td>
</tr>
<tr>
<td>VFR</td>
<td>Visual Flight Rules</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Chapter 1 - Introduction

1.1 Introduction

Ischemic heart disease (IHD) is the single leading cause of death for men and women in New Zealand, accounting for 23% of all mortality (National Heart Foundation of New Zealand, 2004, p. 585). Patients who are diagnosed with a myocardial infarction and are treated early with reperfusion therapy have a significantly increased quality of life and life expectancy (National Heart Foundation of Australia, 2005). Reperfusion therapy may occur by coronary artery bypass graft (CABG), percutaneous coronary intervention (PCI), or thrombolysis, the former two being only undertaken within tertiary cardiac facilities.

New Zealand people who require surgical reperfusion, that is CABG or PCI for IHD are referred to one of five tertiary facilities (Auckland, Christchurch, Dunedin, Hamilton, Wellington). People who live outside of these locations and require surgical reperfusion are transported by air ambulance to one of these centres. Most air ambulances in New Zealand are unpressurized which may expose patients to significant levels of hypoxemia which may have an adverse outcome on their health event.

The objective was to describe the demographic and clinical characteristics of patients who have an unplanned readmission to a regional hospital after undergoing percutaneous coronary angioplasty at a tertiary hospital.

The population for this study consisted of all patients discharged from one tertiary hospital who had undergone surgical reperfusion between 1 January 2000 and 31 December 2008. Data collection was undertaken by data extraction from the New
Zealand National Minimum Dataset (NMDS) and from a regional hospital aeromedical transport database.

In keeping with aviation convention, all units of measure are given in imperial measurements throughout this research unless otherwise stated. Barometric pressure is expressed in millimetres of mercury (mmHg) unless otherwise stated. All flight altitudes are expressed in hundreds of feet and are above mean sea level (AMSL).

The term ‘cabin altitude’ is used to describe the pressure within an aircraft at altitude. While the correct terminology is cabin pressure, in this thesis, in keeping with the published literature the term ‘cabin altitude’ is used and is expressed in feet (ft) equivalent to the altitude which corresponds to that pressure.
1.2 Background

Ischemic heart disease (IHD) is the leading cause of death in New Zealand and accounts for 23% of all deaths. Age adjusted mortality rates of Māori and Pacific island peoples are significantly higher than for Europeans (Ministry of Health, 2008). Māori males over the age of 65 are three to four times more likely to die from heart disease than any other ethnic group (Robson & Harris, 2007). A number of studies have demonstrated that percutaneous coronary intervention (PCI) improves six months mortality statistics and this procedure is now recommended as the treatment of choice for revascularization of patients with IHD (Sharma, 1998).

IHD has two distinct categories, acute coronary syndromes (ACS) and chronic heart disease. ACS is a group of acute events defined by their nature, biochemical markers and electrocardiographic results. ACS comprises unstable angina (UA), ST segment elevating myocardial infarction (STEMI) and non-ST segment elevating myocardial infarction (NSTEMI). UA is angina which occurs at rest which changes or worsens with increasing frequency, or occurs in a crescendo pattern. In UA there are no acute changes on electrocardiograph (ECG), and UA is not associated with changes in biochemical markers.

STEMI is a myocardial infarction diagnosed by changes in biochemical markers as well as ST segment elevation identified on ECG and NSTEMI is differentiated from STEMI by the absence of ECG changes. Evidence-based practice now recommends PCI for both STEMI and NSTEMI patients as the primary intervention (National Heart Foundation of Australia, 2005).
Admission rates for IHD in New Zealand have been increasing over the past decade and are anticipated to increase into the future; this is in part due to increasing rates of readmission of people known to have IHD (Chan, Wright, Tobias, Mann, & Jackson, 2008). Cardiovascular disease affects one in every six people and will rise to one in every four by 2050. Australia spends 11% of its total healthcare budget on cardiovascular disease (Access Economics, 2005).

The guidelines for the management of acute myocardial infarction (AMI) recommend PCI as the treatment of choice for patients who experience chest pain, present to hospital within twelve hours and are diagnosed with AMI. Additionally patients who present to hospitals without PCI facilities and are within two hours transit time of a hospital with PCI facilities should be transferred to that hospital for PCI (National Heart Foundation of Australia, 2005).

Hawke’s Bay residents who undergo PCI in Wellington hospital and are discharged home from Wellington and are entitled to subsidized travel will have their repatriation transport arranged by the Hawke’s Bay District Health Board (HBDHB). This transport will be either air ambulance, commercial aircraft or bus. The mode of transport will be determined by availability of air ambulances, whereby the HBDHB encourages the use of the air ambulance to minimize the cost of transport by commercial means. Discharged patients are viewed as opportunistic transports, and there is no clinical reason for the transportation in an air ambulance.

1.3 The Researcher’s Interest

My interest into the effects of hypoxemia on patients with heart disease has arisen from my work as a certified flight nurse for the Hawke’s Bay District Health Board (HBDHB). My introduction to the aeromedical transportation guidelines for patients
occurred when I undertook my first vocational aeromedical studies at the HBDHB. Subsequently while attending the New Zealand Flight Nurses Association (NZFNA) introductory flight training, I was able to discuss some of my concerns regarding the effects of hypoxia on cardiac patient transport with the course instructor. He advised the attendees that the currently used guidelines were outdated and should not be relied upon for use. After undertaking tertiary aviation nursing studies in 2008 I found that there was a paucity of research to support the existing New Zealand transportation guidelines of patients in unpressurized air ambulances.

Research is the foundation of evidence based practice, it forms the basis for the development of standards of practice which may be disseminated and replicated in different health care settings (The Joanna Briggs Institute). In my role as an assessor for the HBDHB professional development and recognition program and as a certified flight nurse, I am required to assess nurses’ use of evidence and research as the basis for their professional practice (Kennedy, 2004; New Zealand Flight Nurses Association, 2007). It is also incumbent upon me to also provide the evidence for my professional practice.

Patients who live in regional New Zealand and undergo PCI in tertiary hospitals may be repatriated by pressurized or unpressurized air ambulance or commercial aircraft. These aircraft expose the patient to varying levels of hypoxia. This transportation may occur within 24 hours of undergoing PCI. These patients are usually older adults and may have comorbidities which may exacerbate the effects of hypoxia. This thesis will investigate the relationships between repatriation transport and unplanned readmission post PCI. It will describe the characteristics of the readmitted patients and quantify the risk of readmission for different aircraft and patients with different comorbidities.
1.4 Thesis Outline

Chapter 1 Introduction
This introductory chapter provides an outline of the overall thesis, along with subject relevance for the researcher, research aims and research significance. It also includes an outline of the following chapters, the literature review, methodology, findings, discussion, conclusion and recommendations.

Chapter 2 Background
The background gives the reader information on laws of gases, altitude physiology, aviation physiology issues impacting on air ambulance provision and the current state of air ambulance service provision in New Zealand.

Chapter 3 Literature Review
A review of the research literature was performed across a number of fields including aviation physiology and cardiac dysfunction. These are described in this chapter. The final focus is on research into the transportation of cardiac patient’s post-cardiac event and treatment. Themes in the literature are discussed in relation to the proposed research. Deficits in the previous research are identified supporting the need for further research in this area.

Chapter 4 Methodology
The rationale for use of a quantitative research design will be examined. The data collection tool along with ethical considerations and processes are discussed with regard to the rationale for choosing the method, its strengths, weaknesses and applicability to the research.
Chapter 5 Findings and Discussion

Chapter five analyses the results and discusses the findings in relation to the research question. Recommendations from this research have been expressed in this final chapter with reference to the assessment and aeromedical transportation of cardiac patients. The focus of this chapter is on overall results with a summary provided in relation to the research aims and questions.

Chapter 6 Conclusions and Recommendations

Study strengths and limitations are discussed along with implications of this study for nursing with recommendations and opportunities for further research identified.
Chapter 2 - Background

2.1 The Earth's atmosphere

The earth’s atmosphere can be divided into a number of successive layers from the surface of the earth. These layers are the troposphere, stratosphere, mesosphere, thermosphere, and the exosphere. The troposphere supports life on earth and extends from the earth’s surface to between 23,000 ft at the polar regions and 56,000 ft at the Equator (Martin, 2003). The composition of the atmosphere remains constant up to 70,000 ft, with the following being the major constituent gases; Nitrogen 78.08%, Oxygen 20.95%, Argon 0.93%, Carbon Dioxide 0.038% and water vapour 1% (Blumen & Rinnert, 1995). However, while the percentage of each of the gases remains constant the total pressure of the gases are reduced with increasing altitude resulting in a decrease in the partial pressure of the component gases.

A Standard Day is a meteorological term which is used in aviation to accurately calculate flight altitude. The two key components of a standard day for aviators are temperature and barometric pressure. The standard day temperature is +15° Celsius, and has a barometric pressure of 1013 hectopascals at mean sea level. Changes in temperature affect an aircraft’s lift, and barometric pressure is used to calculate height above mean sea level at any given point. Table 1 demonstrates the changes in pressure and temperature at various altitudes on a standard day.
### Table 1

**Temperature and Pressure on a Standard Day**

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Barometric Pressure (mmHg)</th>
<th>Atmospheric Temperature (Celsius)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level</td>
<td>760</td>
<td>+15.0</td>
</tr>
<tr>
<td>1,000</td>
<td>732</td>
<td>+13.0</td>
</tr>
<tr>
<td>2,000</td>
<td>711</td>
<td>+11.0</td>
</tr>
<tr>
<td>3,000</td>
<td>687</td>
<td>+9.1</td>
</tr>
<tr>
<td>4,000</td>
<td>653</td>
<td>+7.1</td>
</tr>
<tr>
<td>5,000</td>
<td>629</td>
<td>+5.1</td>
</tr>
<tr>
<td>6,000</td>
<td>604</td>
<td>+3.1</td>
</tr>
<tr>
<td>7,000</td>
<td>582</td>
<td>+1.1</td>
</tr>
<tr>
<td>8,000</td>
<td>558</td>
<td>-0.9</td>
</tr>
<tr>
<td>9,000</td>
<td>543</td>
<td>-2.8</td>
</tr>
<tr>
<td>10,000</td>
<td>523</td>
<td>-4.8</td>
</tr>
</tbody>
</table>

### 2.2 Laws of Gases

An understanding of altitude physiology relies on an appreciation of the laws of physics which dictate the behaviour of gases when exposed to changes in pressure, volume or temperature (Martin, 2003). The laws which have relevance in aviation and altitude physiology include Boyle’s, Dalton’s and Henry’s laws. Each of these laws will be discussed and how they affect homeostasis.

#### 2.2.1 Boyle’s Law

For a fixed amount of an ideal gas kept at a fixed temperature, \( P \) [pressure] and \( V \) [volume] are inversely proportional, and this may be expressed as \( P_1V_1 = P_2V_2 \) (Blumen & Rinnert, 1995). This may be observed in an aircraft; as it ascends in altitude, the barometric pressure will decrease and the gas in enclosed spaces will expand. At 18,000 ft a gas will double in volume from its sea level state. This will have a direct effect on any person travelling in an aircraft unable to maintain a sea level cabin altitude. It will manifest itself by expansion of gasses trapped within the gut, sinuses, lungs or other body cavities.
2.2.2 Dalton’s Law of Partial Pressure

The total pressure exerted by a gaseous mixture is equal to the sum of the partial pressures of each individual component in a gas mixture $P_t = P_1 + P_2 + P_3 + \ldots + P_y$ (Blumen & Rinnert, 1995). When combined with Boyle’s Law, as the altitude increases and barometric pressure decreases, the partial pressure of each gas will decrease. Table 2 demonstrates the fall in atmospheric PO$_2$ from sea level to 10,000 ft, as the partial pressure of oxygen decreases as a function of decreasing total barometric pressure (Christensen, Ryg, Refvem, & Skjonsberg, 2000).
### Table 2

**Effects of Altitude on Partial Pressures of Oxygen**

<table>
<thead>
<tr>
<th>Altitude (Ft)</th>
<th>Atmospheric Po$_2$ (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level</td>
<td>159</td>
</tr>
<tr>
<td>1,000</td>
<td>153</td>
</tr>
<tr>
<td>2,000</td>
<td>148</td>
</tr>
<tr>
<td>3,000</td>
<td>142</td>
</tr>
<tr>
<td>4,000</td>
<td>137</td>
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<tr>
<td>5,000</td>
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<td>7,000</td>
<td>121</td>
</tr>
<tr>
<td>8,000</td>
<td>116</td>
</tr>
<tr>
<td>9,000</td>
<td>113</td>
</tr>
<tr>
<td>10,000</td>
<td>109</td>
</tr>
</tbody>
</table>

#### 2.2.3 Henry’s Law

At a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid (Blumen & Rinnert, 1995).

Henry’s law defines how soluble a gas is in a liquid, based a concept that gases have a tendency to move from an area of higher concentration to an area of lower concentration. It states that increasing the pressure of the gas above a liquid will allow more gas to enter into the liquid, and conversely if the pressure of a gas above a liquid is released, then the gas within the liquid will evolve from the liquid to meet the reduction in pressure above the liquid.

#### 2.3 Aircraft cabin pressurization

Since Aristotle (384-322 BC) first described the difficulties experienced by his contemporaries climbing Mount Olympus there has been an awareness that increased altitude was associated with hypoxia (Regnier, 2008). The first recorded deaths from hypoxia in flight were during the ill fated flight of the balloon “Zenith” on April 15th, 1875 when Joseph Crocé-Spinelli and Théodore Sivel perished during an
ascent in excess of 28,000 ft (De Fonvielle, 1875). The actual altitude achieved during this ascent as measured by barometer was reported in the journal Nature as 42,000 ft.

By the First World War aviators were routinely being fitted with oxygen masks to prevent the effects of hypoxia during combat operations. To overcome the effects of hypoxia during high altitude flight, aircraft designers created the pressurized cabin. The first commercial pressurized aircraft, the Boeing 307 was developed in 1938 (McFarland, 1971).

Fixed wing aircraft can now be broadly defined into two distinct categories; pressurized and unpressurized aircraft. The use of unpressurized aircraft is restricted to operations less than 13,000 ft where supplementary oxygen for crew and passengers is not required. Airlines operating aircraft above 13,000 ft which feature a pressurized cabin are required to do so by various aviation regulations.

All pressurized aircraft have a maximum allowable cabin pressure differential: that is the maximum allowable difference between the internal cabin pressure and ambient atmospheric pressure, expressed in pounds per square inch (psi). Pressurized aircraft maintain a set cabin pressure by compressing air from the outside and transferring it into the aircraft cabin, and having a regulator “bleed” valve in the tail of the aircraft, which controls the internal cabin pressure by reducing excess pressure automatically as and when required. This process is controlled by a cabin altitude differential system, and will be automatically set by the onboard cabin air management system in most commercial aircraft, but is manually set in some military aircraft. Aircraft cabin pressures are expressed in psi, however the Federal
Aviation Administration (FAA) refers to cabin pressures in feet (ft) and it is referred to as the cabin altitude.

Higher pressure differentials increase stress on the airframe and will lead to a shortening of airframe life, as the continuous cycling between high and low pressure differentials may lead to metal fatigue of the airframe. This fatigue was famously demonstrated in the catastrophic failure of the pressure cabin of Aloha Airlines flight 243 (Bureau of Accident Investigations, 1989).

McFarland (1971) identifies that cabin altitude limits for commercial aircraft operating in the United States were originally set at 12,000 ft in 1941, and later revised to 8,000 ft. The latter decision was based on the realization that a number of airports in South America are at this altitude, one of which Mexico City, is situated at approximately 7,200 ft. Ernsting (1978, p. 497) describes the research which led to the development of the 8,000 ft cabin altitude decision. Ernsting states that under routine operating conditions, the aircraft cabin altitude should ideally not exceed 5,000 – 6,000 ft.

‘Practical experience in transport operations also gives support of this conclusion since reduction of the cabin altitude from 8,000 ft to 6,000 ft is associated with a lower incidence of otitic barotrauma and disturbances in passengers with cardiorespiratory disease’

(Ernsting, 1978).

It has also been reported that aircraft manufacturers adopted the 8,000 ft cabin altitude limit as a compromise between passenger comfort and design life of the aircraft (Aerospace Medical Association, 2008). The FAA requires air transport aircraft to be able to maintain a cabin altitude of 8,000 ft at maximum operating
altitude (Federal Aviation Administration, 2006), while in New Zealand the maximum cabin altitude must not be greater than 10,000 ft (Civil Aviation Authority of New Zealand, 2006).

A number of studies of the actual cabin pressures at various altitudes have been conducted (Aldrette & Aldrette, 1983; Cottrell, 1988; Gong, 1992; Seccombe, Kelly, & Peters, 2005); all studies found that cabin altitudes in commercial aircraft very rarely exceeded 8,000 ft. Cottrell found the average maximum cabin altitude of 204 commercial aircraft flights was 6214 ft, while Aldrette and Aldrette found that cabin altitude was lowest in older aircraft. This differed from Cottrell who found that newer aircraft designs had higher airframe pressure differentials leading to lower cabin altitude at cruise altitude. Seccombe et al. found that an altitude of 6,500 ft was reached for less than one percent of flight time.

Air New Zealand operates three different pressurized aircraft on regional domestic air routes; Avions de Transport Régional ATR-72, Beechcraft 1900D, Bombardier Q-300. Cabin altitudes for these aircraft are identified in Table 3; this table identifies the cabin altitude when the aircraft is at normal cruise altitude and when it is flown at the maximum altitude recommended by the aircraft manufacturer.

Table 3
Cabin Altitude of Regional Commercial Aircraft in New Zealand.

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Normal Cruise Altitude (25,000 ft)</th>
<th>Maximum Operating Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATR-72</td>
<td>6,000</td>
<td>6,750</td>
</tr>
<tr>
<td>Beechcraft 1900D</td>
<td>9,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Bombardier Q-300</td>
<td>6,000</td>
<td>8,000</td>
</tr>
</tbody>
</table>

(Source: M. Wiles-Pickard, Air New Zealand Consulting personal communication March 2009)
2.4 Aeromedical transportation

The use of aircraft for medical purposes can be traced back to the beginning of powered flight with the first recorded use of an aircraft for patient transport occurring in France in 1916, when a French built Dorand AR was used to evacuate wounded Serbian soldiers. One of the first aeromedical services for civilian patient transport was the Royal Flying Doctor Service (RFDS) which was established in 1923 to service people in remote parts of Australia. The use of fixed wing aircraft for inter hospital transportation of patients was first established in 1967 by the New South Wales Air Ambulance Service (Holleran, 2003). Similar air ambulance services can now be found in most western countries. Air ambulance operators in Australia, Canada and the United States primarily utilize pressurized fixed wing and rotor wing aircraft for inter-hospital transfers.

2.5 New Zealand Air Ambulance Provision

In New Zealand, air ambulance transport has evolved to meet the demands of a country characterized by a population density less than half the Organization for Economic Cooperation and Development (OECD) average, in which one quarter of the population lives outside urban areas (Statistics New Zealand, 2001).

Air ambulances are operated by commercial aircraft operators and charitable trusts, which in turn are contracted by DHBs and the Accident Compensation Corporation (ACC) for patient transport service provision. Aircrew are provided by the aircraft operator, while medical, nursing and other clinical staff are provided by the DHB. The fixed wing air ambulance fleet in New Zealand is comprised of 14 dedicated air ambulances, of which six are pressurized (National Ambulance Sector Office, 2008). They are based in locations around New Zealand as demonstrated in Figure
3. There are also a number of charter aircraft with air ambulance certification. These charter aircraft are both pressurized and unpressurized.

Fixed wing aircraft undertook in excess of 3000 inter-hospital transfer missions in 2003. The average per hour cost of an unpressurized air ambulance transfer is less than half that of a pressurized air ambulance hourly rate. Seventy three percent of all fixed wing flying time in 2003 was undertaken by unpressurized air ambulances (Ministry of Health 2004a).

The New Zealand air ambulance fleet composition is varied, with five different pressurized aircraft models, and two unpressurized models. There are five Piper Navajo and three Piper Seneca aircraft: which are twin piston engine unpressurized aircraft and have an operational service ceiling of 10,000 ft without the use of supplementary oxygen by the pilot. The pressurized air ambulance fleet is able to fly at significantly greater altitudes than this. Figure 4 shows cabin altitude and the associated flight level for each of the pressurized aircraft. Increasing the flight altitude of an aircraft improves the safety through reduction of weather related issues such as storm activity.

*Figure 3 Operational Bases of Fixed Wing Air Ambulances.*
Altitudes at or greater than 15,000 ft are referred to as flight level, and recorded as FL and the first three digits of the altitude. Thus 15,000 ft becomes FL150, and 20,000 ft becomes FL200.

### 2.6 New Zealand Topography

New Zealand is a mountainous country, with main dividing ranges in both the North and South islands. The North Island requires instrument flight rules (IFR) with flights to be above 8,000 ft in the southern and eastern zones. The South Island has extensive mountain ranges in excess of 10,000 ft and 90% of the land mass is classified by the Civil Aviation Authority as mountainous. The topography of New Zealand influences the altitude and flight paths of all commercial aircraft activities in both islands as demonstrated in Figure 5.

Aircraft following IFR plans will fly on predetermined flight paths which are published and maintained by the Airways Corporation of New Zealand. The designated IFR flight plan between Napier and Wellington will be Napier, Dannevirke, Palmerston North, Paraparaumu, and Wellington and will attain an altitude of 10,000 ft (Airways Corporation New Zealand). An aircraft operator wishing to significantly deviate from
this path will be required to fly by visual flight rules (VFR), and restrictions to altitude and route will apply.

![Terrain Maps of New Zealand](image)

Figure 5 Terrain Maps of New Zealand

### 2.7 Transportation to Tertiary Care

Publicly funded interventional cardiology and cardio-thoracic services, including CABG and PCI are provided in Auckland, Hamilton, Wellington, Christchurch and Dunedin hospitals. Inpatients from other hospitals requiring PCI or CABG will be routinely transported to these hospitals by fixed wing air ambulance for treatment. This will be undertaken via one of the aircraft described previously, and given the limited use of pressurized aircraft, will most likely be by an unpressurised air ambulance. When flying an IFR plan in an unpressurised air ambulance to Auckland, Christchurch and Wellington hospitals, the flight altitude will exceed 9,000 ft which is 7,000 ft above that which is recommended for patients with an AMI (Aerospace Medical Association, 2008; American College of Chest Physicians, 1960). The flight altitude is above those altitudes at which published research on the
effects of hypoxia in cardiac patients exist. Anecdotal information from flight nurses confirms that cardiac patients are transported at 10,000 ft routinely and occasionally up to 13,000 ft in unpressurized air ambulances.

2.8 Respiratory Physiology

Arterial oxygen tension (PaO₂) is the partial pressure of unbound oxygen within arterial blood. PaO₂ is determined by inspired oxygen concentration, barometric pressure, alveolar ventilation and diffusion of oxygen from the alveoli to the pulmonary capillaries and distribution and matching of ventilation and perfusion (Treacher & Leach, 1998). At sea level the partial pressure of oxygen (PO₂) reaching the alveolus is 110 millimetres of mercury (mmHg). Oxygen depleted blood returning to the lungs from the systemic circulation will have a PO₂ of 40 mmHg and a partial pressure of carbon dioxide (PCO₂) of 46 mmHg. As blood passes through the pulmonary capillaries oxygen binds with haemoglobin to form oxyhaemoglobin and the PCO₂ will drop from 46 mmHg to 40 mmHg (Ernsting, 1988). The effects of altitude on PO₂ at the alveolar level can be seen in Table 4.

<table>
<thead>
<tr>
<th>Altitude (Ft)</th>
<th>Barometric Pressure (mmHg)</th>
<th>Atmospheric PO₂ (mmHg)</th>
<th>Alveolar PO₂ (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level</td>
<td>760</td>
<td>159</td>
<td>110</td>
</tr>
<tr>
<td>1,000</td>
<td>732</td>
<td>153</td>
<td>104</td>
</tr>
<tr>
<td>2,000</td>
<td>711</td>
<td>148</td>
<td>99</td>
</tr>
<tr>
<td>3,000</td>
<td>687</td>
<td>142</td>
<td>94</td>
</tr>
<tr>
<td>4,000</td>
<td>653</td>
<td>137</td>
<td>89</td>
</tr>
<tr>
<td>5,000</td>
<td>629</td>
<td>131</td>
<td>85</td>
</tr>
<tr>
<td>6,000</td>
<td>604</td>
<td>126</td>
<td>80</td>
</tr>
<tr>
<td>7,000</td>
<td>582</td>
<td>121</td>
<td>74</td>
</tr>
<tr>
<td>8,000</td>
<td>558</td>
<td>116</td>
<td>69</td>
</tr>
<tr>
<td>9,000</td>
<td>543</td>
<td>113</td>
<td>65</td>
</tr>
<tr>
<td>10,000</td>
<td>523</td>
<td>109</td>
<td>61</td>
</tr>
</tbody>
</table>
The oxygen haemoglobin disassociation curve as seen in Figure 6 describes the affinity of oxygen in the blood to haemoglobin at various partial pressures; this is expressed as oxygen saturation. Carbon dioxide, carbon monoxide, temperature, pH level, and 2,3-diphosphoglycerate (DPG) all affect the affinity of oxygen to haemoglobin.

2.9 Hypoxia

Hypoxia occurs when there is a mismatch between oxygen supply to tissues and oxygen demand of those tissues (Treacher & Leach, 1998). Hypoxias are classified by the causative factor group; hypoxic, anaemic, histotoxic and stagnant hypoxia (Blumen & Rinnert, 1995). A person with a PaO₂ of 60 mmHg or less is considered to be hypoxemic.

*Hypoxic Hypoxia*, also known as hypobaric hypoxia, is caused by inadequate gas exchange through the alveolar capillary membrane (Blumen & Rinnert, 1995, p. 95). It is principally seen at altitude from mountaineering, aviation or acute exposure to high altitudes, for example while in transit at airports at altitude. Hypoxic hypoxia may also present in patients with asthma, chronic obstructive pulmonary disease (COPD), bronchial obstructions, patent foramen ovale, pneumonia, or a
pneumothorax. Hypoxic hypoxia results in both a lower oxygen tension and oxygen saturation levels in the blood.

**Anaemic Hypoxia** is a reduction in the oxygen carrying capacity of the blood, and results from any or a combination of the following; acute blood volume loss, chronic anaemia, carbon monoxide poisoning, and dsyhaemoglobinemias.

**Histotoxic hypoxia** results from an inability of the body to utilize the available oxygen despite its normal delivery to the blood stream. This may be seen in carbon-monoxide poisoning, cyanide poisoning, and alcohol consumption.

**Stagnant hypoxia** is a result of reduced blood flow to the capillaries; it may result from mechanical failure of the heart, such as heart failure, valvular disease or congenital abnormalities. It also occurs as a result of peripheral venous pooling resulting from immobility.

All hypoxias are additive by nature, and each individual’s response to hypoxia will vary according to age, gender, physical activity, diet, and fatigue status (Johnson-Joseph, Kelso, & Marshall, 2006).

### 2.9.1 Normobaric Hypoxia

Normobaric hypoxia occurs when there is an exposure to a lower atmospheric oxygen concentration with no associated change in barometric pressure, whereas hypobaric hypoxia has an associated decrease in the barometric pressure. Normobaric and hypobaric hypoxia have been demonstrated to have significantly different effects on diffusion of oxygen into the pulmonary circulation. Compared to normobaric hypoxia, hypobaric hypoxia leads to greater hypoxemia, hypocapnia and
a lower arterial oxygen saturation (Savourey, Launay, Besnard, Guinet, & Travers, 2003). Clinical research into the effects of altitude on cardiac responses is normally carried out using lowered inspired oxygen concentrations rather than by decreasing barometric pressure, which may give inaccurate results (Martin, Bradley, Buick, Bradbury, & Elborn, 2007; Phillips, McConnell, & Smith, 1988; Roche et al., 2002). Hypobaric hypoxia affects aircraft passengers due to the decreased barometric pressures associated with increased cabin altitudes. Therefore studies which use normobaric hypoxia may not demonstrate the same outcomes as those studies which subject the patients to hypobaric hypoxia conditions.

2.9.2 Responses to Hypoxia

The normal physiological responses in healthy adults to hypoxemia are; vasodilatation especially in the coronary vessels, vasoconstriction in the spleen, muscle, pulmonary and cutaneous beds and an increased cardiac output primarily through an increased heart rate. There are significant differences between a hypoxic myocardium and an ischemic myocardium. In a healthy adult the response to myocardial hypoxia is a doubling of coronary blood flow. However the hypoxic response of a diseased heart is not well understood. (Davies & Wedzicha, 1993) The heart uses approximately 11% of total oxygen consumption in adults at rest (Ernsting, 1988). The myocardium normally consumes 60 – 75% of all oxygen delivered to the myocardial tissues therefore it has limited oxygen reserve when compared to other organs (Freudenberger & Carson, 2003).
Chapter 3 - Literature review

3.1 Introduction

The purpose of this literature review is to investigate the impact of cabin altitude on patients with ischemic heart disease and the characteristics of patients transported after undergoing percutaneous coronary intervention.

3.2 Search Strategy

Two search strategies were used to identify key literature in specific fields. The first approach was to undertake a wide search of medical bibliographical databases as a first cut, and then to use a ‘data mining’ approach on selected areas of interest. The United States National Institute of Medicine’s Medline Database, the Cumulative Index for Nursing and Allied Health Literature (CINAHL), and Elsevier’s MD Consult were used to undertake a search of published reports, abstracts and books written in English. Key words used were hypoxia, altitude, cardiac, heart, hypobaric, and air ambulance. No date limiters were placed when searching for aeromedical publications. The second approach was to undertake an ancestry approach or footnote chasing of the literature obtained through the bibliographical search (Polit & Beck, 2007). When no new useful literature appeared the literature search was considered complete.

The following specific areas were searched:

1) Evidence based guidelines for management of ischemic heart disease
2) Aeromedical transportation of patients with cardiovascular diseases
3) Altitude physiology
4) Effects of reduced PO$_2$ on the heart
5) Aircraft cabin air quality systems
A number of seminal documents which dated back to 1936, 1960 and the early nineteen seventies were identified and obtained. These documents were included as they provide valuable information on rationales for subsequent decisions on cabin altitude restrictions. Documents which specifically relate to aeromedical transportation were included as many subsequent reports, guidelines and practice manuals use these as the basis for their practice. A literature search primarily using the Medline database was undertaken as described earlier; specifically identifying air travel or aviation with angina, acute coronary syndrome or myocardial infarction.

The literature review will be structured into four sections; contributing factors to ischaemic heart disease (IHD), the physiological responses to altitude, current aviation transportation guidelines for cardiac patients and finally a discussion of aeromedical transportation research.

3.3 Physiological responses to altitude

On acute exposure to altitude the normal physiological responses include increased heart rate, increased coronary circulation through dilation of epicardial coronary arteries, and increased cardiac contractility. However these are all at the expense of increased myocardial oxygen consumption which increases at a rate of 1% per 300 ft above 4,500 ft (Bartsch & Gibbs, 2007). This response occurs due to the fall in PaO2 and a corresponding fall in saturation of oxygen in the blood (SaO2) as demonstrated in Figure 7.
3.4 Age related responses to altitude

Disease processes and environmental influences are not the sole factors responsible for changes in lung function. Muhm (2004) assessed lung function by various ages groups and found that 2% of healthy people with no lung disease aged 25 or less demonstrated a PaO$_2$ of 50 or less at sea level, whereas 40% of those who were 65 or older demonstrated a PaO$_2$ of 50 or less at sea level. Muhm's study along with Kronenberg and Drages' (1973) study demonstrated that age related pulmonary changes affect the ability of older adults to maintain PaO$_2$.

3.5 The diseased heart to altitude

Patients with coronary artery disease display a number of changes in their myocardial oxygen demand, as opposed to healthy subjects. Morgan Alexander, Nicoli and Brammell (1990) found that there was a 11% reduction in oxygen uptake in patients with coronary artery disease who were acutely exposed to an altitude of 5,000 ft. They also noted that exertional angina occurred at lower workloads when exposed to altitude as opposed to sea level in the population studied.
Wyss, Koepfli, Fretz, Seebauer, Schirlo, and Kaufmann (2003) found that coronary flow reserve was significantly impaired in patients with coronary artery disease who undertook light exercise at 8,000 ft, whereas the control subjects were able to maintain coronary flow reserve until 12,000 ft. In the same study the control group used 50% of their maximal myocardial blood flow whereas the patient group used 90% of their maximal myocardial blood flow performing the same operation at altitude.

### 3.6 Contributing factors to IHD

#### 3.6.1 Ethnicity

In New Zealand ethnicity has been found to be an independent risk factor for cardiovascular disease, with indigenous people being at significantly higher risk of heart disease than Europeans (Ellis et al., 2004; Khot et al., 2003; Roe et al., 2008).

Māori men were seven times more likely to be admitted to hospital with heart failure than non-Māori men, and the age-sex standardised death rates for Māori over the period 2000 – 2004 were 2.3 times than those for non-Māori (Robson & Harris, 2007, p. 151).

#### 3.6.2 Heart Failure

Heart failure is a complex syndrome which occurs when the heart fails to pump enough blood, resulting in systemic fluid retention, dyspnoea, and peripheral oedema. Heart failure results in shortness of breath on exertion in early stages and may progress to orthopnoea, and nocturnal dyspnoea. The precipitating events which cause heart failure are coronary artery disease, cardiomyopathy, hypertension, valvular heart disease and congenital heart disease. Heart failure
severity is graded according to functional limitations according to the New York Heart Association Functional Classification System.

Heart failure has a poor prognosis (Sharma, 1998, p. 643), and the National Nutrition Examination Survey (He et al., 2001) found that the following were the top five independent risk factors for the development of heart failure: ischemic heart disease (61%); cigarette smoking (16%); hypertension (10%); obesity (8%); and diabetes (3%).

3.7 Cardiac co-morbidities

3.7.1 Anaemia

Anaemia is defined as a reduction of haemoglobin in the blood below 120 grams per litre of blood in non-pregnant women or 130 grams per litre in adult men (McLean, Cogswell, Egli, Wojdyla, & de Benoist, 2009). Anaemia is an independent risk factor for cardiovascular disease, and is associated with an increased incidence of left ventricular dysfunction. Studies of animals which have ischemic heart disease have shown anaemia to significantly impair the heart’s response to hypoxia (Pereira & Sarnak, 2003). No randomized controlled studies in humans of the effects of anaemia in IHD have been conducted.

As the level of anaemia increases, the ability to meet tissue oxygen demand decreases, and the normal physiological responses are to increase heart rate, myocardial contractility and arterial tone. This leads to increased oxygen availability to the tissues, however there is a negative effect of increasing oxygen demand placed on the body by this activity (Freudenberger & Carson, 2003, p. 357). Freudenberger and Carson also note that in two of the studies they reviewed, more
ischemic events were seen in anaemic patients undergoing surgery than normal patients.

Magosso and Ursino (2004) found that while both normal and anaemic subjects who were exposed to hypobaric hypoxia had a significant rise in cardiac output, the anaemic subjects were at life threatening levels of hypoxemia when exposed to moderate altitudes.

3.7.2 Chronic Obstructive Pulmonary Disease

Chronic obstructive pulmonary disease (COPD) is a restrictive lung disease commonly associated with lifelong smokers (Warner, 2006). COPD affects the respiratory physiology by reducing the elastic recoil of the interstitial lung tissue, reducing bronchial tract size, and increasing respiratory effort to maintain oxygenation. Table 5 demonstrates the prevalence of COPD in adults aged over 44 years by ethnic group in New Zealand (Ministry of Health, 2008).

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>Prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European/ Other</td>
<td>6.7% (5.9–7.5)</td>
</tr>
<tr>
<td>Māori</td>
<td>12.9% (9.4–16.4)</td>
</tr>
<tr>
<td>Pacific</td>
<td>5.7% (3.3–9.1)</td>
</tr>
<tr>
<td>Asian</td>
<td>2.4% (1.2–4.1)</td>
</tr>
</tbody>
</table>

A number of studies found that patients with COPD developed severe hypoxemia at altitudes significantly lower that those found in commercial aircraft cabins. These studies also found that it is more difficult to predict the level of hypoxemia in patients with COPD than it is to predict in healthy individuals (Christensen et al., 2000; Christensen, Ryg, Refvem, & Skjonsberg, 2002; Muhm, 2004). In two separate studies Muhm (2004) and Akero and colleagues (2005) found that age was an independent determinant of PaO₂ with 81% of healthy people aged 65 or over likely to have a PaO₂ of 55 or less at an altitude of 8,000 ft (Akero, Christensen,
Edvardsen, & Skjonsberg, 2005). Christensen et al. (2000) found that in patients with COPD, 86% developed hypoxemia at 8,000 ft and all COPD patients would develop hypoxemia in hypobaric chamber exposure to 10,000 ft. Christensen and colleagues (2000) concluded that there was no correlation between pre-flight PaO2 and the development of hypoxemia at altitude. Furthermore, light exercise produced profound hypoxia in all COPD subjects at 8,000 ft.

3.7.3 Dysglycemia

Dysglycemia is a term used to encapsulate a number of metabolic conditions including Type I and II diabetes, gestational diabetes, impaired glucose tolerance and other conditions which are typified by elevated levels of blood glucose. Dysglycemia is either due to an absence of insulin in the blood or a degree of insulin resistance. These conditions are recognised as a major modifiable cardiovascular disease risk factor (Grundy, Benjamin et al., 1999; Ritz, 2007; Sharma, 1998, p. 164).

It is anticipated that Type II diabetes rates in New Zealand will increase by 45% between 2001 and 2011, of which two-thirds will be a result of non modifiable demographic changes in the population (Ministry of Health, 2007). Table 6 demonstrates the prevalence of Type II diabetes in New Zealand by ethnic group.

Table 6

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>Prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European/ Other</td>
<td>4.3 % (3.8 - 4.8)</td>
</tr>
<tr>
<td>Māori</td>
<td>5.8 % (4.9 - 6.7)</td>
</tr>
<tr>
<td>Pacific</td>
<td>10.0 % (8.1 - 11.8)</td>
</tr>
<tr>
<td>Asian</td>
<td>6.5 % (5.4 - 7.7)</td>
</tr>
</tbody>
</table>

People with diabetes are at high risk of developing microangiopathy. Microangiopathy is a process whereby the endothelial lining of arterioles take in more glucose than normal, and become abnormally thickened and weak. This
results in decreased internal lumen diameters, decreased blood flow, increased incidence of thrombus formation and occlusion. This in turn leads to a reduction in supply of oxygen to the tissues of the affected area (Grundy, Benjamin et al., 1999). Additionally a reduced supply of blood to nerves results in neuropathy which, when it affects the heart, is known as Cardiac Autonomic Neuropathy.

Cardiac Autonomic Neuropathy increases risk of silent myocardial ischemia, infarction and death, and while the process and association are not fully understood, Scott and Kench (2004) assert there is a significant body of evidence which links cardiac autonomic neuropathy with cardiac sympathetic dysfunction and decreased coronary blood flow.

Diabetic patients have altered responses to stress stimuli, and this altered response has been demonstrated as both a diminished ventilatory response and a diminished heart rate response to hypoxia (Nishimura et al., 1989).

3.8 Lifestyle factors

Lifestyle factors such as tobacco smoking, obesity and physical inactivity have been demonstrated to be independent factors in cardiovascular disease (Jairath, 1999). Two of these factors directly affect the ability of the body to meet oxygen demand and have been demonstrated to have a direct relationship to tissue hypoxia.

3.8.1 Tobacco Smoking

The relationship between tobacco smoking and cardiovascular diseases is well documented in research literature. Health related effects of smoking are chronic in nature and take a number of years before they have a significant observable impact on a persons health (Vos & Begg, 2007). However, a number of chemical reactions
(such as the production of carbon monoxide) occur in the burning of tobacco, and carbon monoxide has an immediate impact on the uptake of oxygen by the blood.

Carbon monoxide’s affinity to haemoglobin is approximately 240 times more than that of oxygen. It has a half life of 320 minutes (six hours) when breathing air, falling to 72 minutes when breathing 100% oxygen (Blumenthal, 2001). It has been noted that while the half life of 320 minutes is generally accepted, Cronenberger Mould, Roethig and Sarkar (2008) suggest that in some smokers the half life may be as long as 31 hours. Carbon monoxide levels in adult non-smokers are generally less than 1%, but rise to between 8% and 15% in adult cigarette smokers. Martin (2006, p. 155) suggests that heavy smokers have a 2,000 ft physiological disadvantage at sea level when compared to people who do not smoke or who have stopped smoking, due to their elevated carboxyhaemoglobin levels. This means that the smoker may have an alveolar PO₂ of 99 mmHg as opposed to a non-smoker having an alveolar PO₂ of 110 mmHg at sea level.

Carbon monoxide shifts the oxygen-haemoglobin disassociation curve to the left, thereby decreasing the ability of oxygen to unbind at a cellular level. This inability to unbind oxygen will persist at very low partial pressures of oxygen, therefore impeding the normal physiological response to hypoxia (Warner, 2006).

Smoking rates are recorded differently by different government agencies. Two categories of reporting are common, with a “current smoker” being defined as a person who engages in smoking on a daily basis, and “former smoker” being a person who regularly smoked in the past but has not smoked in the past three months (National Centre for Classification in Health, 2008). In this thesis smoking status will refer to current smokers, former smokers or people who have never
smoked. Smoking rates vary by ethnicity and deprivation index. Reported rates for Māori people smoking are noted as being twice for non-Māori (44.1% vs. 21.4%) (Robson & Harris, 2007, p. 148).

3.8.2 Obesity

The World Health Organisation (2009) defines overweight and obesity as abnormal or excessive fat accumulation that may impair health. Body mass index (BMI) is a simple index of weight-for-size that is commonly used in classifying overweight and obesity in population groups and individuals.

Obesity is associated with increased incidence of cardiovascular disease, and an increasing BMI has been correlated with increased incidence of ACS (Jensen et al., 2008). The American Heart Association identifies obesity as a major risk factor for cardiovascular disease. The risk for IHD patients is accentuated when obesity has a predominant abdominal component (Grundy, Pasternak, Greenland, Smith, & Fuster, 1999). In industrialised countries 40 - 60 % of the population are considered overweight or obese (Sharma, 1998, p. 231). In New Zealand 22% of the adult population are obese, and 38% of the adult Māori population are considered obese (Ministry of Health, 2004b).

Obesity is associated with reductions in PaO₂ and obstructive sleep apnoea (Mokhlesi & Tulaimat, 2007). Changes of ventilatory patterns in normal breathing, and significant changes of regional lung perfusion with changes of body position for both sedated and conscious patients have been associated with obesity (Yamane et al., 2008). Case reports of respiratory failure in patients with morbid obesity after airline travel have been reported (Toff, 1993).
3.9 Cabin altitude restrictions for cardiac patients

The effect of hypoxia and cardio-respiratory disease is a widely researched field. McFarland and Edwards (1938) undertook seminal research into the effects of cabin altitude on air crew and passengers at altitudes between 9,000 and 12,000 ft in 1936 on trans-oceanic flights, and subsequent research was undertaken by the Royal Air Force during world war two into the effects of cabin altitude on pilot performance (McFarland, 1971).

Research in the field of altitude exposure has focussed on alterations in respiratory physiology at altitude. However, there have been a small number of studies which have looked at the effects of altitude on the heart. Malagon, Grounds and Bennett (1996) identified the majority of altitude studies have been conducted in mountainous conditions over a number of day which allows for acclimatization to occur. In the aeromedical transport environment, patients may be exposed to altitude very acutely with no opportunity for acclimatization or compensation to occur.

The American College of Chest Physicians (ACCP) was the first organisation to develop guidelines regarding air travel for people with heart disease. These guidelines were developed and published in 1960, and subsequently a number of other organisations have developed aeromedical transportation guidelines. These include the Aerospace Medical Association, the American Society of Hospital Based Emergency Aero Medical Services (ASHBEAMS), Health Canada and Martin’s guidelines. Guidelines from other organisations such as the Alaskan Air Medical Service, Royal Flying Doctor Service and the New Zealand Flight Nurses Association (NZFNA) appear to be based on the ACCP guidelines. The first four are summarised in Table 7.
Table 7
Commercial Cabin Altitude Recommendations by Authority

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Any symptomatic cardio-respiratory disease</td>
<td>8,000</td>
<td>10,000</td>
<td>Not Stated</td>
<td>10,000</td>
</tr>
<tr>
<td>More than mildly symptomatic disease</td>
<td>6,000*</td>
<td>6,000</td>
<td>Not Stated</td>
<td>8,000</td>
</tr>
<tr>
<td>Myocardial Infarction &gt; 8 weeks</td>
<td>4,000</td>
<td>4,000</td>
<td>4,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Stable Angina</td>
<td>4,000</td>
<td>6,000</td>
<td>4,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Severe cardiac disease with cyanosis or recent decompensation</td>
<td>4,000*</td>
<td>4,000*</td>
<td>2,000*</td>
<td>4,000</td>
</tr>
<tr>
<td>Mild CHF</td>
<td>4,000*</td>
<td>4,000</td>
<td>4,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Myocardial Infarction less than 8 weeks previous</td>
<td>2,000*</td>
<td>2,000*</td>
<td>2,000*</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Table notes: All altitudes recorded in ft above mean sea level.
* Indicates oxygen required to be available to patients where oxygen saturations drop below 92%.

The original ACCP (1960) guidelines are a consensus statement; no reference is made to research and there is no bibliography in the document. Given the age of the document it must be considered Level IV evidence within the Scottish Intercollegiate Guidelines Network evidence framework (2007).

The ASHBEAMS guidelines are not directly available as they are secondary sourced from the Hawke’s Bay DHB Aeromedical Training for Flight Personnel workbook (2006). The original guidelines are referenced but have not been able to be independently validated; therefore the weight of evidence cannot be relied upon. These guidelines as reproduced in the workbook are less restrictive on altitude limit exposures for cardiac patients than the original ACCP guidelines.

Martin (2006, p. 159) has reproduced the ACCP guidelines in a table format, however in formatting of the table a number of alterations to the intent of the guidelines have occurred. These alterations have resulted in variations to the upper limits of altitude exposure, and are found to be consistently higher than the original
ACCP guidelines. Martin has acknowledged that there are errors in his reproduction of the tables, acknowledging the error may be a result of secondary sourcing of the data (personal communication, 25 March 2009, Appendix G). Martin’s guidelines are unchanged from the first and second editions of his book.

The Health Canada Guidelines (2002) appear to follow the ACCP guidelines, with some minor changes. The Health Canada guidelines have no referencing and there is no authorship of the guidelines. These guidelines appear to be the most conservative of all of the published guidelines.

In New Zealand a number of different guidelines are used as references for management of cardiac patients, however in the NZFNA Introductory Flight Nursing Course Manual (2007), the ASHBEAMS guidelines are referenced as the source of information for altitude limits.

Research demonstrates that patients with cardiac disease are at risk of hypoxia at altitudes experienced in normal commercial aircraft travel (Cottrell, 1988; Iwasaki et al., 2006; Phillips et al., 1988; Wyss et al., 2003). These effects have been demonstrated to occur at altitudes significantly lower than 10,000 ft. There appears to be a number of guidelines for the transportation of cardiac patients, but these guidelines do not appear to be evidence based. Some of the guidelines have been found to be erroneous or misleading and others are unable to be independently verified. This situation leads to the conclusion that the current guidelines require expedient review to ensure that they meet standards for evidence based practice.
3.10 Cardiac Aeromedical Studies

‘Cardiorespiratory events are the leading cause of death during commercial air travel’

(Gong, 1992).

The volume of research into the effects of transportation of cardiac patients is modest by comparative standards of research. Searching multiple databases as outlined earlier identified very few published papers. Table 8 outlines these studies.

Table 8
Air medical transportation of cardiac patients

<table>
<thead>
<tr>
<th>Source</th>
<th>Year</th>
<th>Patient Number</th>
<th>Transport Mode</th>
<th>Diagnosis</th>
<th>Altitude</th>
<th>Exposure</th>
<th>Days after presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaplan</td>
<td>1987</td>
<td>104</td>
<td>Helicopter</td>
<td>AMI</td>
<td>Not stated</td>
<td>0–36 hours</td>
<td></td>
</tr>
<tr>
<td>Malagon</td>
<td>1996</td>
<td>2</td>
<td>Air Ambulance</td>
<td>MI</td>
<td>8,000 ft</td>
<td>Not stated</td>
<td></td>
</tr>
<tr>
<td>Zahger</td>
<td>2000</td>
<td>21</td>
<td>Commercial</td>
<td>MI / ACS</td>
<td>Not stated</td>
<td>18.2 ± 11</td>
<td></td>
</tr>
<tr>
<td>Roby</td>
<td>2002</td>
<td>30</td>
<td>Commercial</td>
<td>STEMI</td>
<td>Not stated</td>
<td>10-27</td>
<td></td>
</tr>
<tr>
<td>Essebag</td>
<td>2003</td>
<td>Systematic</td>
<td>Commercial / Air Ambulance</td>
<td>NSTEMI</td>
<td>Not stated</td>
<td>2–53</td>
<td></td>
</tr>
<tr>
<td>Essebag</td>
<td>2003</td>
<td>Systematic</td>
<td>Commercial / Air Ambulance</td>
<td>MI / ACS</td>
<td>Not stated</td>
<td>3–53</td>
<td></td>
</tr>
<tr>
<td>Thomas</td>
<td>2006</td>
<td>213</td>
<td>Commercial</td>
<td>STEMI / CHF</td>
<td>Not stated</td>
<td>6–38</td>
<td></td>
</tr>
</tbody>
</table>

Note: The first author of each study is listed in the above table, full details of authorship occur in the body of the text and in the bibliography.

Kaplan, Walsh and Burney (1987) studied the transportation of 104 patients with suspected acute myocardial infarction (AMI) who were transported by helicopter from primary and secondary care settings to a large tertiary hospital for coronary artery reperfusion. The mean age was 54.5 years, 75% were men, and 99% had ischemic ECG changes. All patients were transported within 36 hours (mean 6.0 ± 5.5 hours) of onset of first symptom of AMI. The patients were transported in a helicopter a mean distance of 32 miles. Within the 50 mile radius of the University of Michigan Hospital, the maximum ground level above mean sea level was 1,000 ft, which would infer a helicopter cabin altitude of not greater than 2,500 ft above sea level for all flights undertaken. Thirteen patients had complications in flight, four had serious hypotension and four had arrhythmias requiring treatment. No patients died.
during transport. Thirty-one percent needed some physician intervention during the flight. This study’s limitations in relation to the proposed research are the patients were being transported to a tertiary facility for PCI, whereas the proposed study will examine patients post interventional therapy. The cabin altitude has been assumed to be 2,500 ft or less, and there was an absence of flight duration information. The results appear to be a case series and no post flight follow up was documented in the paper.

Malagon, Grounds and Bennett (1996) reported a case series of seven patients and seven volunteers and the measurement of cardiac output between patients and volunteers while in flight. This study included two patients with a diagnosis of myocardial infarction. The study reports significant variation in cardiac output between sea level and flight altitude, with the most variation occurring in the patient group; however the actual flight altitude achieved is not discussed in the report. Malagon et al. also report the oxygen saturation differential drop was significantly larger in the patient group than the volunteer group. While the size of the study limits its applicability, the data elements used for data collection are robust and warrant further investigation.

Zahger, Leibowitz, Tabbs and Weiss (2000) undertook a prospective study of 21 tourists visiting Israel in May 1999 who were admitted to the coronary care unit of Hadassah University Hospital. The demographic data is very limited; only age was provided (70 ± 13 years). The average time from admission to flight was 18.2 ± 11 days, and all patients flew on commercial aircraft, 17 of whom flew to North America with a travel duration of 12.5 ± 3 hours. One patient is reported to have subsequently died in the follow up period, and one patient required readmission to hospital for angina. Study limitations include an undefined time for the follow up, the
only study admission criteria appears to be admission to CCU as an overseas tourist
and there is no documentation of co-morbidity or lifestyle factors. Zahger et al.’s
study has limited relevance to the proposed research.

Roby, Lee and Hopkins (2002) undertook a single-blind, controlled trial to assess
the safety of air travel without the use of supplementary oxygen by patients who
were at least two weeks post myocardial infarction. This was achieved by
prospective random assignment of patients to receive supplementary oxygen or not
during commercial flight. Thirty eight patients were enrolled with 19 in each arm of
the study. The groups were reported as not being statistically different in age, sex or
flight duration. Holter monitors were used to record cardiac rhythm for the flight
duration. Analysis of these found no ischemic events. Thirteen people had minor
end points of transient low oxygen saturation, or transient ventricular tachycardia.
This study demonstrates a high level of reliability as it uses a randomization process
and objective data recorded in the form of Holter monitoring for assessment of
myocardial ischemia. Limitations on its value to the proposed research are that it
fails to identify cabin altitude, and therefore no definitive assessment of the PaO2 of
either group can be accurately made.

Essebag, Lutchmedial and Churchill-Smith (2001) undertook a clinical audit of 109
cardiac patients repatriated to the United Kingdom between 1 January and 1
October 1998. This audit assessed 83 air ambulance (AA) patients and 23
commercial transports (C). The patient profile was myocardial infarction (MI) (63%),
unstable angina (UA) (31%) congestive heart failure (CHF) (21%) and arrhythmia
(17%). Seventy six percent were male with a mean age of 65.7 years (range 33-89)
and females averaged 71.3 years (range 47-87). The study found that AA patients
were transported 6.7 days earlier than C patients, and that AA transportation was
associated with a higher in-flight complication rate (10% versus 4%), However patients who had complicated MI were significantly more likely to have in-flight complications than uncomplicated MI (50% versus 13%). The most common in-flight complication was chest pain in flight (6), followed by decreased oxygen saturation.

Essebag’s et al.’s study gave a level of detail not seen in other reports. It provided information on a range of variables including chest pain free period prior to flight, days since admission, and intravenous medications used during hospitalisation. The data was provided for both types of transportation. The study identified the air ambulance as a Lear Jet 35, which had a cabin pressure differential of 9.2 giving a maximum cabin altitude of 6,000 ft at FL380 and of 5,000 ft at FL350. However the types of commercial aircraft used was not identified. Essebag identified a number of weaknesses with the study, namely that it was a case series of a heterogeneous patient population selected by retrospective chart analysis. The accuracy of the charts from which the data was collected could not be verified, and the sample size and event rate was insufficient to allow for statistical power analysis. In addition Essebag and colleagues report that no follow up of the population was undertaken to ascertain the delayed effects of the transportation. The report was the most comprehensive found in print, and will be of benefit to the proposed research; however a lack of co-morbidity data is a limitation.

Thomas et al (2006) studied the medical records of 213 patients repatriated to the United Kingdom between 1 April 2004 and 30 November 2005, by an international air medical repatriation company. The study’s aim was to determine the safety of commercial air transportation after STEMI or NSTEMI event. Demographic information given was 73% male with a mean age 61 years. The transport time varied between 4 – 6 hours, and 17.9% of STEMI patients had asymptomatic
hypoxia (as measured by pulse oximetry recorded levels less than 92%) during repatriation compared with 14.1% of NSTEMI patients. The three patients who experienced angina during flight had undergone PCI for STEMI prior to repatriation. Patients were repatriated 6-38 (mean 12.9) days post presentation. No randomization occurred in the study, and it appears to be a case series presentation.

Thomas et al.’s (2006) study had the largest enrolment and provides a good guide to the proposed investigation. However limitations include the length of time between event and repatriation, and the absence of defined cabin pressures. It may however be assumed that the cabin pressures were less than 6,500 ft according to Seccombe’s research (Seccombe et al., 2005). No post flight follow up was documented in the paper.

In summary, all but one of the studies were of patients who had been transported in pressurized aircraft. If the aircraft manufacturers design the aircraft according to the FAA requirements (Federal Aviation Administration, 2006), then we may infer that the cabin altitude will have rarely exceeded 8,000 ft and would have been less than 6,000 ft for the majority of the flights if we accept Seccombe’s research (2005). Only Malagon’s study identified the cabin altitude patients were exposed to during flight. While three of the studies have significant enrolments (Essebag, 2002; Kaplan, Walsh, & Burney, 1987; Thomas et al., 2006), they are not readily comparable to the proposed study as they fail to define the minimum cabin altitude attained during flight. This is a significant variable in any study of exposure to altitude as the maximum cabin altitude is required to determine the lowest ambient cabin PO2.
Chapter 4 - Methodology

4.1 Introduction

The literature review has shown there is limited research in relation to the effects of hypoxia in cardiac patients in the aviation setting. This chapter will describe the research design selected and the rationale for implementation. The chapter will also discuss and describe the data sample, acquisition, analysis and ethical considerations.

4.2 Research Design

Polit and Beck (2007) describe nursing research as a systematic inquiry designed to develop issues of importance to the nursing profession. As part of the Nursing Council of New Zealand’s competencies for practice, Registered Nurses must demonstrate that their policies, procedure and clinical practice are based on relevant research (Nursing Council of New Zealand, 2005). All of the studies identified in the literature review were quantitative in nature, and this approach supports a quantitative approach to the research question.

4.3 Data Acquisition

Data for this research were obtained from two separate databases. Patient admission event data was obtained from the NMDS, and patient flight records were obtained from the HBDHB patient transport database.

A request for information was sent to the New Zealand Health Information Service (NZHIS) for all patient discharges from Wellington Hospital who underwent an invasive cardiac procedure between 1 January 2000 and 31 December 2008. The NZHIS provided data extracts from the NMDS. These extracts were supplied as separate files. One file contained index admission event information: admission
dates; patient age at admission; sex; ethnicity; DHB of domicile; and admission length of stay data. Another file contained International Statistical Classification of Diseases and Related Health Problems (ICD) codes for each index admission record. A third file contained admission records for any subsequent admission within a three day period from the index admission discharge date to any hospital in New Zealand.

A request for information was sent to HBDHB for all patient transport records from Wellington Hospital between 1 January 2000 and 31 December 2008. The HBDHB provided a single data extract from the patient transport service database. This extract contained patient transport date and aircraft type. The files were imported into Microsoft (MS) Access 2007 (Redmond, WA, USA) and a data mapping process was undertaken.

The primary key for each NMDS record was a unique identifier which allowed mapping ICD codes to demographic data. The use of the National Health Index (NHI) identifier allowed the readmission admission events to be matched to an index admission event through date windowing of the index and readmission events. Only the first readmission event for each index event was included in the dataset regardless of the admission diagnosis. The two records were then joined to give a unique record. The principal diagnosis codes were mapped to twelve diagnosis groups to provide meaningful grouping for statistical analysis. The ICD codes files were scanned for diagnosis codes of anemia, cholesterol, current smoker, current / past smoker, diabetes, hypertension, and obesity. Once these records were identified within the file, dichotomous variables were set for each instance found. This was necessary to allow for logistic regression to be performed using the comorbidity data.
Four additional fields (CABG, PCI, angiography, and other invasive cardiac procedure) were added to map principal procedures to dichotomous variables. A number of patients had multiple interventional procedures recorded within a single admission, and these patient's records were prioritized as follows, CABG, PCI, angiogram and other. This resulted in each patient having a single principal procedure for each admission.

4.4 Data Validation

The data conversion process required a number of intermediate steps in MS Access, therefore validation of the import and mapping was undertaken by selecting a random number of records and comparing the records to the source data. This process identified no errors in the MS Access records.

The HBDHB transport database had undergone a number of changes in both database type and operating system since it’s implementation in 1999. To ensure reliability of transport data extract, an audit was undertaken of all of the transport records, log books and monthly job sheets. Where errors were detected the source document of the flight record or monthly job log was taken as correct and the spreadsheet edited accordingly.

4.5 Admission Event Data

All admission records included; admission start and end date, whether the event was an acute or elective admission, whether the patient was transferred from or to another hospital as source of admission and separation. All records were given an event year, determined by the event start date. Seven admission events which commenced in 1999, but which concluded in the following year were included in the year 2000 statistics.
The index admission events were sorted by NHI and date to identify multiple admissions for patients. All index event records were assigned an admission episode sequence number. This sequence number allowed analysis of first index events for each patient to occur, and all demographic reporting was undertaken on index event number one. The maximum number of admissions identified was five index admissions.

4.6 Diagnosis Codes

The World Health Organisation (WHO) provide ICD codes to classify diseases, sequela, abnormal findings, complaints, and external causes of injury or disease. Every health condition can be assigned to a unique category and given a code, up to six characters long. Disease categories are grouped by similar characteristics and by body system. All public hospitals in New Zealand collect inpatient and day case separation diagnosis and intervention data using the Australian modified version of the 10th revision of this code set (ICD-10-AM). This revision includes procedure codes, based on the Australian Medicare Benefits Schedule codes (MBS) which may be used to record major health interventions or procedures. Each procedure or intervention can be assigned a procedure date. These codes have been adopted by the WHO and are referred to as the International Classification of Health Interventions (ICHI).

All ICD codes recorded on the NMDS for each health event were obtained, 95% of the records had 13 codes or fewer, and the maximum number of ICD codes assigned to a unique event was 36.
4.7 Study inclusion criteria

An age inclusion criteria was set at between 35 and 90 years of age. The lower limit was set to ensure that patients who were being treated for congenital conditions were excluded from the study, and the upper parameter was set so as to minimize skewing of data in the analysis phase.

When examining unplanned readmissions it was decided to use Chambers and Clarke’s (1990) definition: “the next subsequent admission of a patient as an immediate (that is, emergency or unplanned) admission ... within a defined interval of a previous (index) discharge taking place within a defined reference period.”

A decision to limit the reference period to three days was chosen as it was the investigators opinion that admissions which would be the result of physiological stress from acute altitude exposure would diminish after this period. This is supported by Tsai’s (2001) findings that 45.7% of unplanned readmissions occur within five days of index event discharge date, and is therefore possible to conclude that the number of unrelated readmissions would be minimized.

The reliability in use of hospital administrative datasets has been tested and found to be a valid method of undertaking clinical research. However, in this research it was found that the recording of admission type and admission source often conflicted with index discharge codes, with patients who were acute admissions being recorded as hospital transfers. This was illogical, and therefore I created a matrix for determination of unplanned versus planned readmission.

The following business rules were developed;

- If a patient was discharged routinely, and re-presented as an acute admission they were an unplanned readmission.
• If a patient was a discharge transfer to other hospital and were an arranged admission, they were a planned admission.
• If a patient was discharged routinely and the readmission date was greater than the index discharge date, they were an unplanned readmission.
• If a patient was a discharge transfer and the readmission date was greater than the index discharge date, they were an unplanned readmission.

4.8 Prepared Data

The final file layout for data analysis contained the following attributes; NHI Number, DHB of domicile, sex, age, ethnicity, index admission date, index discharge date, admission sequence number, discharge type, discharge location, length of stay, principal diagnosis, principal procedure flags, comorbidity flags, readmission flag, readmission date, readmission discharge date, readmission type, readmission source, principal diagnosis, and repatriation transport mode.

4.9 Statistical analysis

In this research analyses were performed using SPSS version 14 (Chicago, IL, USA). Analyses included univariate Pearson chi-square test and odds ratio to explore the association between the presence of each of the transport modes and unplanned readmission within three days of discharge. Binary logistic regression analysis was also performed to determine the independent effects of age, sex, ethnicity, anemia, cholesterol, diabetes, hypertension, smoking, diagnosis and the principal procedures on unplanned readmission with three days of discharge.

Binary logistic regression is used to predict a discrete outcome from a set of variables that may be continuous, discrete, dichotomous, or a mix of any of these (DiCenso, Guyatt, & Ciliska, 2005). The dependent variable is dichotomous: there is an unplanned readmission to hospital or there isn’t.
The odds ratio is the odds of an event which occurs in one group also occurring in another group (DiCenso et al., 2005). An odd ratio of one indicates no association with the exposure, whereas greater than one indicates that the exposure is more likely to occur in the study group than the control group, and if it is less than one it is less likely to occur in the study group than the control group.

A Confidence Interval (CI) is the range of plausible differences of probable outcomes. The confidence interval will narrow with an increase in the number of samples of a population taken. Confidence intervals for research are usually calculated at 95% or 99% (Polit & Beck, 2007, p. 585). This study used a CI of 95%.

4.10 Ethical Considerations

4.10.1 Confidentiality

The research design and data collection from the NMDS and the hospital transport database excluded collection of personally identifiable information. Additionally only the researcher and research statistician had access to the raw data. No NHI numbers will be published as part of the findings. The database supplied from the NZHIS has password protection and the CD Rom is stored according to the requirements of the ethics committees.

4.10.2 Cultural Considerations

Prior to embarking on this research project, the researcher met with the Service Manager of the Māori Health Unit at the local District Health Board for guidance and assistance in support of the research. A meeting with the DHBs Māori Liaison Officer was arranged and after discussion of the proposed research, it was agreed
that on completion of the study a copy of the research findings be made available to the Māori Health Unit. The Māori Liaison Officer presented the researcher with a copy of Hauora – Māori Standards of Health IV, to assist with understanding the issues of equity of access relating to health services for Māori. No potential harm to participants was anticipated with this research, as the data is retrospective and no personally identifiable information will be published.

4.10.3 Ethical Approval

Ethical approval for this research was obtained following application to the Multi Region Ethics Committee, the local District Health Board Research Committee and the Eastern Institute of Technology Research Approval Committee. Approval letters from these committees are attached as Appendix C, D and E respectively.

4.10.4 Conflict of interest

I am currently employed as a Flight Nurse for the regional District Health Board which the patients in this research are repatriated to by air ambulance. I have been in this role for four years and am responsible for the safe transportation of patients to and from the DHB by air ambulance. In my role as a Flight Nurse I am required to follow standing orders and guidelines for the safe transportation of patients to and from the DHB.

As part of the data acquisition process, it was determined that excluding any personally identifiable patient information would minimise the risk related to conflict of interest. Additionally the period under examination has a finish date prior to my enrolment in this thesis at the Eastern Institute of Technology.
4.10.5 Funding

Funding for the research paper was provided by the Hawke's Bay District Health Board, and through the Hawke’s Bay Medical Research Foundation. No funding for this research was sought or obtained from any air ambulance service providers.
Chapter 5 - Findings and Discussion

5.1 Introduction

The seven District Health Boards (DHBs) of the lower North Island and upper South Island had a 2006 Census population of 485,005 in the 35 to 90 year age group (Figure 8 (Statistics New Zealand, 2006)). To avoid pseudo-replication of demographic data when undertaking statistical analysis, the database was split by admission episode. All demographic reporting is therefore conducted on physical patients rather than admission event. There were 16,850 patients recorded in the database.

Wellington hospital is the tertiary cardio-thoracic centre for patients living in the lower North Island and upper South Island of New Zealand. Patients are referred from Hawke’s Bay, Hutt, MidCentral, Nelson-Marlborough, Wairarapa and Whanganui DHBs.

Demographic data will be presented as numbers, percentages and means, and standard deviations will be used to describe the variability within ranges.

5.2 Admission data

There were a total of 16,850 patients who met the criteria for inclusion in this study, of which 9.3% had more than one index admission. Admission records were split by admission sequence and only the first two admission sequences were analysed for statistical purposes, which accounted for 99.4% of index admissions. Hawke’s Bay domiciled patients comprised 13.5% of the study group and accounted for 2,474 admissions.
index admissions, with 556 readmissions (22%) in comparison to 17.9% within three days for the total group.

5.3 Age

Population age and sex demographics change over the life span, with women having longer life expectancies than men. The mean age of all admitted patients was 63.5 ±11.21 years.

Increasing age was associated with an increase in the rate of readmission with older patients being more likely to be re-admitted (P = 0.001, O.R. 1.059, CI: 1.031 – 1.087).

Hawke’s Bay patients were older (64.41 ± 11.20) than the average age of the study population (63.45 ± 11.21) on index admission and on readmission (68.01 ± 11.30 vs. 65.74 ± 11.73).

5.4 Ethnicity

The Ministry of Health determines prioritized ethnicity by utilizing Statistics New Zealand’s ‘Understanding and working with ethnicity data’ (Didham, Potter, & Allan, 2005). Prioritized ethnicity was used as the basis for all ethnicity analysis in this project. To provide meaningful data for analysis, three ethnic meta groups were identified; European, Māori and Other.

Table 9 demonstrates the target population ethnicity for each DHB area.
<table>
<thead>
<tr>
<th>District Health Board (DHB) of Domicile</th>
<th>European</th>
<th>Māori</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawke's Bay</td>
<td>65.7%</td>
<td>13.9%</td>
<td>20.3%</td>
</tr>
<tr>
<td>Hutt</td>
<td>66.3%</td>
<td>15.8%</td>
<td>18%</td>
</tr>
<tr>
<td>MidCentral</td>
<td>71.4%</td>
<td>16.8%</td>
<td>11.7%</td>
</tr>
<tr>
<td>Nelson - Marlborough</td>
<td>77.8%</td>
<td>8.4%</td>
<td>13.7%</td>
</tr>
<tr>
<td>Wellington</td>
<td>66.8%</td>
<td>9.9%</td>
<td>23.3%</td>
</tr>
<tr>
<td>Whanganui</td>
<td>69.9%</td>
<td>23.2%</td>
<td>6.9%</td>
</tr>
<tr>
<td>Wairarappa</td>
<td>77.1%</td>
<td>14.2%</td>
<td>8.7%</td>
</tr>
</tbody>
</table>

In this research 12.9% of Hawke's Bay patients were Māori. Māori had a slightly higher, but non-significant, readmission rate of 14.6% compared to other Hawke's Bay domiciled readmissions. The average age of Hawke's Bay Māori patients was younger than Hawke's Bay European patients (58.38 years ± 9.83 vs. 69.62 ± 11.18) on readmission and were more likely to present on index admission with myocardial infarction than European patients (38.2% vs. 31.9%) although this difference was not significant.

5.5 Gender

Gender was a significant variable, with males being more likely to be re-admitted (P< .001, OR 1.17). This finding is comparable to results from other studies (Ajani et al., 2008; Roe et al., 2008; Van de Werf et al., 2005).

5.6 Access to Treatment

While Wellington Hospital provides the majority of tertiary cardiac services to the seven DHBs of the lower North Island and upper South Island, and three other public hospitals perform interventional cardiology. Hawke's Bay and MidCentral hospitals have access to coronary angiography and Nelson Marlborough commenced PCI in 2007. Hutt, Wairarappa and Whanganui have no interventional cardiology service. DHBs with tertiary cardiac services had a lower percentage of admissions to Wellington (Figure 10) based on population; this may be a result of
some coronary angiography being performed within those DHBs before referral to Wellington hospital.

Wairarappa and Whanganui have access commensurate with their regional populations. The 1% of other DHBs may be accounted for by acute presentations of patients from outside the region.

Admissions to Wellington hospital for target population by DHB of domicile

5.7 Readmission Data

Patients who presented to any hospital in New Zealand within three days from the date of discharge were included in the research. This group formed one cohort to determine general readmission rates for all patients from Wellington hospital. These patients had their first readmission event linked to the index event. There were 3,329 readmissions for the period 1 January 2000 – 31 December 2008, representing a 17.9% readmission rate. The day of discharge is considered day zero. Hutt hospital had the highest readmission rate in the region, due to an early discharge agreement between Wellington and Hutt hospitals. Hawke’s Bay’s readmission rate was the next highest. In Figure 11, readmission length of stay increased at a similar rate to the index admission length of stay across all DHBs. This increasing readmission trend is of concern for future health planning and funding.
This increase in length of stay was not associated with changes in population demographics. However, Chan et al. (2008) identified that while the overall number of people with IHD presenting to hospital has stabilized, there is an increasing trend for patients with known IHD to have increasing numbers of readmissions. This may lead to an increase in the complexity of admission and therefore an increase in the length of stay for both admission and readmission.

### 5.8 Interventional Procedures

To enable statistical analysis four procedural groups were created, and each admission assigned a primary procedural group, based on a complexity of procedure priority. CABG receiving the highest weighting, PCI second, angiogram third and other cardiac procedure fourth. This weighting was developed based on the author's knowledge of the complexity of each of the procedure groups. Table 10 presents the total number of interventions by procedure for the research population for the period.

Table 10
Total Numbers and Percentages and Hawke's Bay Percentages of Cardiac Interventions

<table>
<thead>
<tr>
<th>Interventional Procedure</th>
<th>Number</th>
<th>%</th>
<th>Hawke's Bay %</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG</td>
<td>2216</td>
<td>11.9</td>
<td>13.9</td>
</tr>
<tr>
<td>PCI</td>
<td>5435</td>
<td>29.3</td>
<td>40.1</td>
</tr>
<tr>
<td>Coronary Angiogram</td>
<td>7182</td>
<td>38.7</td>
<td>26.4</td>
</tr>
<tr>
<td>Other Cardiac Procedure</td>
<td>3744</td>
<td>20.2</td>
<td>19.9</td>
</tr>
<tr>
<td><strong>Total Interventional Procedures</strong></td>
<td><strong>18577</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All procedures were noted to have an increasing readmission rate (Figure 12) except for other cardiac procedures; however PCI patients were significantly less likely to have an unplanned readmission than any other group (P 0.01 OR 0.451).

![Figure 12 Readmission percentages by procedure](image)

5.9 Year of admission

Total admissions over the eight years increased from 1,688 admissions in 2000 to 2,159 admissions in 2008. During this period two years had negative growth in admission volumes, however there was an overall increase from 2000 – 2008 of 27.9%. The growth in volume of admissions and readmissions is plotted in Figure 13. Further analysis of the data found that year of index admission was an independent variable for readmission (P 0.002). This may be due to a number of factors, such as changes in surgeon, equipment and changes in practices. It is not possible to test these variables without access to specific data which is not captured...
by the NMDS but may be available at Wellington hospital. However, the significance of this variation in readmissions between years requires further investigation.

![Readmissions over study period](image)

**Figure 13 Readmissions over study period**

The Hawke’s Bay DHB readmission rate is higher than the all other DHBs combined and is projected to remain higher than the regional rate of readmission as demonstrated in Figure 13. This projection has implications which need assessment for future health funding and planning.

### 5.10 Unplanned Readmissions

An unplanned readmission was any acute readmission to a hospital in New Zealand within three days of discharge from the index event. A total of 335 patients had an unplanned readmission to Hawke’s Bay hospital after repatriation by commercial aircraft or air ambulance. Another 221 patients had an unplanned readmission, but were excluded as the repatriation transport mode was unknown; these patients appear in Table 14, as non-DHB funded transport.
The readmission principal diagnosis was used to identify the primary reason for the unplanned readmission; the principal diagnosis for Hawke’s Bay versus remainder of the population’s readmissions is described in Table 11. Large differences are seen in the acute myocardial infarction and aftercare diagnosis groups.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Hawke’s Bay</th>
<th>Study Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstable angina</td>
<td>8.2 %</td>
<td>10.6 %</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>10.1 %</td>
<td>24.1 %</td>
</tr>
<tr>
<td>Chronic ischemic heart disease</td>
<td>nil</td>
<td>3.6 %</td>
</tr>
<tr>
<td>Aftercare / convalescence</td>
<td>44.7 %</td>
<td>24.3%</td>
</tr>
<tr>
<td>Surgical complications</td>
<td>4.3 %</td>
<td>4.3 %</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td>10.1 %</td>
<td>10.7 %</td>
</tr>
<tr>
<td>Other cardiac condition</td>
<td>15.9 %</td>
<td>17.7 %</td>
</tr>
<tr>
<td>Other non-cardiac condition</td>
<td>6.7 %</td>
<td>4.7 %</td>
</tr>
</tbody>
</table>

A concern with the data on aftercare from Table 11 and the potential negative physiological effects of repatriation via unpressurized air ambulance led to an analysis of readmission by repatriation type. It should be noted that due to the definition of principal diagnosis, the readmission reason and the coded principal diagnosis may differ. In Table 12, unpressurized air ambulance was used to compare the odds ratio for readmission. Unpressurized air ambulance was chosen as this would indicate if there was a significant difference between pressurized and unpressurized air ambulance transport on readmission. However, from the table it is noted that there is no statistical difference between air ambulance types, but there is a significant difference between scheduled air services and air ambulance, which resulted in 65% fewer unplanned readmissions for patients transported by scheduled air services.
Table 12
*Repatriation Statistics*

<table>
<thead>
<tr>
<th>Transport Mode</th>
<th>Prevalence</th>
<th>Significance</th>
<th>O.R.</th>
<th>C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpressurized Air Ambulance</td>
<td>62 %</td>
<td>.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressurized Air Ambulance</td>
<td>33 %</td>
<td>.409</td>
<td>1.293</td>
<td>.702 – 2.383</td>
</tr>
<tr>
<td>Scheduled Air Service</td>
<td>3.5 %</td>
<td>.004</td>
<td>0.356</td>
<td>.176 - .722</td>
</tr>
</tbody>
</table>

Table 12 identified that patients who were transported in air ambulances were more likely to be readmitted to hospital than patients travelling on commercial aircraft. In attempting to understand this phenomenon, it is proposed that risk adverse clinical practices may be at play. This can best be described in a scenario basis, as follows.

Discharged patients who are being repatriated by air ambulance are escorted to the hospital as part of the DHB’s air ambulance policy, this ensures that patients’ relatives are not at the airport, and the discharged patient is not left unaccompanied after arrival at the airport.

During the transit the patient may become short of breath or develop transient chest pain, and is therefore assessed by the flight nurse. Given that the patient will accompany the nurse back to the hospital as per the protocol; the nurse may recommend to the patient that they be assessed by an emergency department (ED) doctor. This in turn leads to a risk aversion strategy within the ED, as the ED doctor refers the patient to the cardiology team. The cardiology team will accept the patient and therefore the patient is admitted to hospital.

These factors do not come into play for patients who are repatriated by commercial aircraft, as there is no clinical intervention, and it is up to the patient to determine if they require medical assistance. Alternately it may be that there is limited time...
exposure to altitude in commercial aircraft, as was found by Seccombe et al. (2005) and therefore there is insufficient time for the effects of hypoxia to develop.

5.11 Comorbidities and readmission

Previous research and expert opinion identifies five major risk factors for myocardial infarction, continued smoking, diabetes, hypertension, dyslipidemia, and obesity (National Heart Foundation of Australia, 2005; National Heart Foundation of New Zealand, 2004; New Zealand Guidelines Group, 2003; Ritz, 2007). While only hypertension and smoking were found to be risk factors in this study [see Table 13], this may be a result of the study design rather than the risk factor themselves or as stated previously it may be due to issues regarding the recording of comorbidity codes by Wellington hospital. It should also be noted that multiple comorbidity analysis was not undertaken in this study.

5.12 Risk Factors

Table 13 examines the relationship between known risk factors of ischemic heart disease and unplanned readmissions to Hawke’s Bay hospital. In this research, hypertension and smoking are associated with an increased risk of readmission for patients in Hawke’s Bay, which is supported by previously identified literature. However, the reported rates for patients who smoke and were obese or had a comorbidity of COPD do not correlate with either Statistics New Zealand data or published data from the Ministry of Health or international research. The low rate of recorded smoking may be a result of the information not being recorded in the admission notes or not being flagged within the medical record. It may also be due to low rates of self reporting in the study population. The obesity percentages may also be the result of recording only those patients who are morbidly obese. The low rates of diagnosing COPD is well established in the literature and the research finding from this study appears to confirm this (Bednarek, Maciejewski, Wozniak,
Kuca, & Zielinski, 2008; Lokke, Lange, Scharling, Fabricius, & Vestbo, 2006; Miravitlles et al., 2009).

Table 13

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Prevalence</th>
<th>Significance</th>
<th>O.R.</th>
<th>C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>16%</td>
<td>.071</td>
<td>1.648</td>
<td>.958 - 2.834</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>22%</td>
<td>.945</td>
<td>0.983</td>
<td>.598 - 1.614</td>
</tr>
<tr>
<td>Obesity</td>
<td>1.8%</td>
<td>.880</td>
<td>0.899</td>
<td>.228 - 3.548</td>
</tr>
<tr>
<td>Smoker</td>
<td>11.9%</td>
<td>.021</td>
<td>2.302</td>
<td>1.135 - 4.669</td>
</tr>
<tr>
<td>Hypertension</td>
<td>48.6%</td>
<td>.047</td>
<td>0.651</td>
<td>.426 - .995</td>
</tr>
<tr>
<td>Anaemia</td>
<td>2.9%</td>
<td>.490</td>
<td>1.556</td>
<td>.443 - 5.464</td>
</tr>
<tr>
<td>COPD</td>
<td>1%</td>
<td>.945</td>
<td>1.060</td>
<td>.201 - 5.589</td>
</tr>
</tbody>
</table>

5.13 Repatriation Transport

Air ambulance utilization rates have been increasing over the past nine years since a policy change relating to funding of patient transport occurred. In 2008 Hawke’s Bay DHB repatriated 81% of discharged patients by air ambulance. However, since 2005 there has been considerable change in the aircraft type used for transportation, moving from predominantly unpressurized to pressurized aircraft as demonstrated in Figure 13. This finding is a result of the aircraft type used to transport patients to the tertiary facilities. However given that there is significant variation in the cost between unpressurized and pressurized air ambulances, further study needs to be conducted into the field of their use in transportation of pre-procedural patients. From projections of utilization, it may be inferred that only pressurized air ambulances will be used from 2011, as demonstrated by the projection of pressurized aircraft in Figure 14. This will have a significant financial impact on the HBDHB. Non-funded transport, that is repatriation transport which was paid for by the patient, has consistently fallen over the research period. This may reflect changes in eligibility and an increasing utilization of the aircraft on repositioning flights by transporting discharged patients in the aircraft.
Figure 14 Discharged Patient Repatriations by Type 2000 - 2008
Chapter 6 - Conclusions and Recommendations

6.1 Air ambulance vs. commercial aircraft

This research has demonstrated that in New Zealand the use of commercial aircraft is associated with a lower unplanned readmission rate than air ambulances. There may be multiple factors at play in this result, and these factors are outside of the scope of this thesis. It is recommended that future studies attempt to identify the factors which lead to increased readmission for patients transported by air ambulance.

6.2 Altitude Guidelines

During this research it became apparent that there are multiple guidelines for aeromedical transportation, none of which appear to be based on clinical research. It was identified that the guidelines all emanate from a single document published fifty years ago, which was designed to provide information for commercial aircraft travel by cardiac patients. Studies of people with heart disease undertaking mountain expeditions demonstrates that there is an increased myocardial demand, increased levels of hypoxia at lower altitudes and increased risk of ischemic events (Alexander, 1994; Hultgren, 1992; Iwasaki et al., 2006; Jackson, 1968; Kanai, Nishihara, Shiga, Shimada, & Saito, 2001). However until evidence based guidelines are developed for aeromedical transportation, a conservative approach should be adopted. This conservative approach should take into account comorbidities of patients and a full pre flight assessment for all patients including discharged patients.

While the study did not find a difference in the readmission rate of patients travelling in unpressurized air ambulance as opposed to pressurized air ambulance, previous
research supports a conservative approach for exposure of cardiac patients to hypoxic environments. Therefore it is recommended that the current guidelines be adhered to until evidence based guidelines are developed.

It is recommended that the New Zealand Flight Nurses Association, as the professional body representing flight nurses co-ordinate the standardisation of these practices across the sector, and develop a single set of guidelines for air ambulance transportation. It is recommended that in developing guidelines a simple tool is designed which covers all cardiac conditions.

6.3 Admission Principal Diagnosis

The Ministry of Health requires that hospitals record the principal reason for an admission to be recorded as the principal diagnosis. Of the unplanned readmissions HBDHB had nearly twice as many readmissions for aftercare or convalescence than the other lower north island (LNI) DHBs. This could indicate that HBDHB’s clinical coders are reporting admissions differently to other DHBs.

A number of patients who were readmitted after a period of greater than 24 hours post index event discharge had a principal diagnosis of aftercare or convalescence. However, these diagnoses are usually recorded for patients who are directly transferred between hospitals. This suggests that a trigger event precipitated the admission for example chest pain, shortness of breath or lethargy and this data may be recorded as secondary and subsequent diagnoses. A limitation of the study was the reliance on ICD codes, and whilst the use of hospital discharge data has been validated as an appropriate tool (Avendano & Soerjomataram, 2008; Powell, Lim, & Heller, 2001), there is still a reliance on standardisation of coding practices to ensure consistency when measuring multiple hospitals data.
No analysis was undertaken on second and subsequent ICD diagnosis codes, if this had been undertaken through the development of a ranking system for ICD diagnosis codes, it may have been possible to identify commonality in the group of patients who required aftercare and convalescence, to determine if these patients had co morbidities or other presenting factors influencing their readmission. Future studies should attempt to identify the patient’s presentation clinical condition rather than the principal treatment which occurs with an ICD code of aftercare or convalescence.

6.4 Administrative dataset reliability

The variation found in the admission and discharge administrative data may be attributed to individual hospital practices on data collection and entry into the hospital system. It is known that the admission administrative data at the Hawke’s Bay DHB is entered from paper records and is not verified with the patient. This practice may lead to errors in the admission dataset occurring. A tension will always exist between administrative functions of a hospital and the ability to use administrative datasets for research purposes. When undertaking research it is important to ascertain the reliability of the dataset prior to undertaking the research.
Afterword

This research was born out of my philosophy to take nothing for granted and for my clinical practice to be evidence based. One of the frustrations in undertaking this research was the paucity of nursing research in the aviation setting. Nurses have been associated with aviation since its inception, and have been pivotal in the development of air ambulance services in many countries. In New Zealand there are only two other Master of Nursing thesis in the aviation field; Brookes (2001) and Houliston (2007). This may be reflective of the role in which aviation nursing is viewed within the DHBs.

There are currently no dedicated full time flight teams in New Zealand, rather flight nursing roles are adjunctive to nurses primary roles in other clinical environments. This adjunctive nature inhibits the development of a professional body of flight nurses, and directly impacts on the ability of nurses to focus research into the field. The current state of play would be analogous to having a group of surgeons who were only permitted to work one day a week as surgeons and the other four days they would be required to work as a General Practitioner or in another discipline. The role of flight nursing is demanding both physically and mentally, it requires nurses who have a range of clinical skills, who can work without supervision and in autonomous practice roles, and without immediate access to support services found in the acute care setting. This requires nurses who can work in advanced practice roles and are competent to work independently.

Within the DHB sector there is limited collaboration in utilization of air ambulance services across New Zealand. This may be a result of the model of funding, in that a large percentage of air ambulance funding is through community donations, and
the community has a belief that it is ‘their’ air ambulance service. This model does not easily lend itself to a nationally integrated air ambulance model.

These issues will continue to inhibit the development of an advanced practice role of the flight nurse within New Zealand, and we may be faced with replacement by paramedics and technicians as has happened in parts of Australia and the United States. Without a strong professional body of evidence which can demonstrate value, and the development of evidence based standards for practice, there will be the opportunity for other health professions to fill the space we currently occupy.
References


Appendix A Conversion of air pressure units to \textit{le Système international d'unités}

<table>
<thead>
<tr>
<th>Feet</th>
<th>Metres</th>
<th>PSI</th>
<th>kPa</th>
<th>inHg</th>
<th>mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>305</td>
<td>14.17</td>
<td>97.70</td>
<td>28.86</td>
<td>732.94</td>
</tr>
<tr>
<td>2000</td>
<td>610</td>
<td>13.66</td>
<td>94.18</td>
<td>27.82</td>
<td>706.66</td>
</tr>
<tr>
<td>3000</td>
<td>914</td>
<td>13.17</td>
<td>90.80</td>
<td>26.82</td>
<td>681.15</td>
</tr>
<tr>
<td>4000</td>
<td>1219</td>
<td>12.69</td>
<td>87.49</td>
<td>25.84</td>
<td>656.39</td>
</tr>
<tr>
<td>5000</td>
<td>1524</td>
<td>12.23</td>
<td>84.32</td>
<td>24.90</td>
<td>632.36</td>
</tr>
<tr>
<td>6000</td>
<td>1829</td>
<td>11.78</td>
<td>81.22</td>
<td>23.98</td>
<td>609.05</td>
</tr>
<tr>
<td>7000</td>
<td>2134</td>
<td>11.34</td>
<td>78.19</td>
<td>23.09</td>
<td>586.44</td>
</tr>
<tr>
<td>8000</td>
<td>2438</td>
<td>10.92</td>
<td>75.29</td>
<td>22.23</td>
<td>564.52</td>
</tr>
<tr>
<td>9000</td>
<td>2743</td>
<td>10.50</td>
<td>72.40</td>
<td>21.39</td>
<td>543.26</td>
</tr>
<tr>
<td>10,000</td>
<td>3048</td>
<td>10.11</td>
<td>69.71</td>
<td>20.58</td>
<td>522.66</td>
</tr>
</tbody>
</table>

PSI = pounds per square inch, kPa = kilopascals, inHg = inches of mercury, mmHg = millimetres of mercury.
Appendix B Data Elements for Data Extraction

Data elements provided by Analytical Services, Ministry of Health
PO Box 5013, Wellington, all data supplied as per NZHIS data definitions.

Data definitions available at www.nzhis.govt.nz/moh.nsf/pagesns/238?Open

Master NHI
Event NHI
Admission source
Admission type
Agency code
Date of birth
Sex
Age at admission
Age at discharge
Ethnic group 1
Ethnic group 2
Ethnic group 3
Prioritised ethnicity
DHB of domicile code
Event type
Event end type
Event start date
Event end date
Event ID
Event leave days
Facility code
Length of stay
Event ID
Clinical code (ICD-10-AM v1)
Diagnosis sequence
Diagnosis type
Operation/procedure date
Appendix C Aviation Technical Assistance

Bruce Brownlie
Director
Air Manawatu Limited

Ruth Northcott
Clinical and Human Resources Manager
CareFlight Medical Services Limited (Australia)

Doug Oliver
Director, Corporate Communications
Cessna Aircraft Company (USA)

Eric Sharma
Product Manager, Program Planning Development & Customer Requirements,
Commercial Aircraft Programs,
Bombardier Aerospace (Canada)

Micheline Wiles-Pickard
Project Manager
Air NZ Consulting
Appendix C Multi-region Ethics Committee Approval

Multi-region Ethics Committee
Ministry of Health
Level 2, 1-3 The Terrace
PO Box 5013
Wellington
Phone (04) 470 0655
(04) 470 0646
Fax (04) 496 2191
Email: multiregion_ethicscommittee@msdh.govt.nz

11 June 2009
Peter Julian Kennedy
19 Fairview Place
Havelock North

Dear Peter

What are the effects of altitude on cardiac patients post percutaneous coronary intervention.

Lead Investigator: Peter Julian Kennedy

MEC09/38/EXP

The above study has been given ethical approval by the Multi-region Ethics Committee.

Approved Documents
- Masterate Research Proposal entitled: "Aeromedical transportation of cardiac patients/What are the effects of cabin altitude on cardiac patients post percutaneous coronary intervention."

Accreditation
The Committee involved in the approval of this study is accredited by the Health Research Council and is constituted and operates in accordance with the Operational Standard for Ethics Committees, April 2006.

Final Report
The study is approved until December 2009. A final report is required at the end of the study and a form to assist with this is available at http://www.ethicscommittees.health.govt.nz. If the study will not be completed as advised, please forward a progress report and an application for extension of ethical approval one month before the above date.

Amendments
It is also a condition of approval that the Committee is advised of any adverse events, if the study does not commence, or the study is altered in any way, including all documentation eg advertisements, letters to prospective participants.

Please quote the above ethics committee reference number in all correspondence.

It should be noted that Ethics Committee approval does not imply any resource commitment or administrative facilitation by any healthcare provider within whose facility the research is to be carried out. Where applicable, authority for this must be obtained separately from the appropriate manager within the organisation.
Yours sincerely

Rebecca Stewart
Multi-region Ethics Committee Administrator
Email: rebecca_stewart@moh.govt.nz
Appendix D Eastern Institute of Technology Approval

Ref: 11/09

3 August 2009

Peter Kennedy
19 Fairview Place
Hastings

Dear Peter,

Thank you for providing clarification to the Committee’s request regarding “Impact upon Maori?”.

Further to our letter of 2 June 2009, I wish to confirm approval of your research project “What are the effects of altitude on patients post percutaneous coronary intervention”.

You are reminded that if the proposal changes in any significant way, then you must inform the Research Committee.

We wish you well for the project.

Kind regards

Jeanette Fifield
Secretary – Research Approvals Committee

Cc: Dr. Bob Marshall, Faculty of Health & Sport Science
    Judy Searle, Faculty of Health & Sport Science

EASTERN INSTITUTE OF TECHNOLOGY
MAIN CAMPUS Gloucester Street, Taradale, Private Bag 1201, Hawke’s Bay Mail Centre, Napier 4142, New Zealand.
Telephone 06 874 8000, Facsimile 06 874 8919, Web www.eit.ac.nz Email info@eit.ac.nz
HASTINGS LEARNING CENTRE Cnr London & Railway Roads, PO Box 1577, Hastings 4150, Telephone 06 974 8530, Facsimile 06 974 8530
CENTRAL HAWKE’S BAY LEARNING CENTRE 51 Russell Street, PO Box 210, Napier 4140, Telephone 06 838 7099, Facsimile 06 838 7098
FLASHLITE LEARNING CENTRE Florence Village, Sweeney Road, Hastings 4120, Telephone 06 874 8945
WAKAIA LEARNING CENTRE Cnr Paul & Queen Streets, Waikato Aitk, Telephone 08 854 7410
HARAIMUT LEARNING CENTRE 10-20 Ruderatus Road, Hanawau, Napier, 4111, Telephone 06 842 0931, Facsimile 06 842 0934

83
3 July 2009

Peter Kennedy
19 Fairview Place
Havelock North

Dear Peter

Re: Hawke's Bay District Health Board Research Application

Thank you for your application to conduct research within the Hawke's Bay District Health Board. I am pleased to advise that your application has been successful.

Please find enclosed a signed copy of your application.

Should you have any queries during your research, I can be contacted during office hours. It would assist if you quoted your registration number in any communication with this office.

Regards

Yours sincerely

Alasdair Williamson RN MSc PhD Candidate
NURSE RESEARCHER

RESEARCH OFFICE
Hawke's Bay District Health Board
Phone 06 878 8109. Fax 06 878 1686. Email: alasdair.williamson@hbdhb.govt.nz
Omahu Road, Private Bag 9014, Hastings, New Zealand.
17 July 2009

Peter Kennedy
19 Fairview Place
Havelock North
NEW ZEALAND

Our ref: PERM/EDU/PETER KENNEDY/17.07.09
Your Ref:

Dear Peter,


Further to your e-mail of 22 June, I am pleased to grant permission for use of Figure 2.3 (p.23), Figure 2.11 (p.34) and Figure 2.13 (p.36) from our book in your research thesis on the subject of 'Aeromedical Transformation of Cardiac Patients, what are the effects of altitude on cardiac patients post percutaneous coronary intervention', for presentation at the Eastern Institute of Technology, Hawke's Bay, New Zealand, on 27 November 2009.

Permission granted is non-exclusive and non-transferable, for one-time, non-profit use only.

No fee is payable.

Please be sure to acknowledge the source and include in the credit line the following notice: "Reproduced by Edward Arnold (Publishers) Ltd".

Good luck with your project!

All best wishes,

Nick Wetton
Permissions Administrator
Subject: Altitude restrictions
From: Terry Martin <emmet2001@doctors.org.uk>
Date: Tue, 24 Mar 2009 13:07:24 +0000
To: peter.kennedy@paradise.net.nz

HL Peter

Thank you for your email. However, I am afraid I am guilty of the greatest sin of not checking the original source of my own researches. Clearly I must have taken the table from a secondary source and used the same citation. That is bad practice, as you have now discovered. Mea culpa!

I will look through my old notes and see if I can shed any light. If so, I'll get back to you asap.

Kind regards

Terry Martin

From: Peter Kennedy [mailto:peter.kennedy@paradise.net.nz]
Sent: Monday, 23 March 2009 8:18 p.m.
To: Katherine Harris
Subject: Email for Terry Martin

HL Katherine,

I have a question for Terry in relation to a table in his book Aeronomedical Transportation: A clinical guide. I would be pleased if you could forward this onto him.

Dear Terry,

I am currently undertaking my Masters of Nursing research and the question I am exploring is:

How does cabin altitude affect the readmission rates of patients after undergoing percutaneous coronary intervention?

In my literature review I have found an anomaly which I cannot explain and would appreciate your assistance / guidance.

On page 159 of the Aeronomedical Transportation: A clinical guide, a table is provided 'Altitude restrictions for patients with cardiopulmonary disease without supplemental oxygen.' This table is attributed to the published paper "Air Travel in Cardiorespiratory Disease"

However on review of the source document there appears a number of alterations between the table and the source document.

In the source document, Altitude limit 1 is 10,000ft.

No patient with suspected or symptomatic cardio-respiratory disease be exposed to altitude limit 1. Mildly symptomatic disease.... should not be exposed above altitude limit 2 (8,000 feet).

It also goes on to state that for certain conditions oxygen should be available at varying altitudes. However in the table on p159 of Aeronomedical Transportation these appear to have been altered.

Whilst these appear to be minor in nature, it appears to be a uniform change which has been reproduced in a number of texts and training manuals.

The reason I pose my question is that I would like to ascertain if there has been an error in reproduction of the table or there is another source document which describes the information differently.

I would appreciate your feedback on this matter.

Kind Regards

Peter Kennedy

Contact Details:
19 Fairview Place,
Havelock North
NEW ZEALAND
Ph: +64-6-8771190
Mob: +64-27-5502992
email: peter.kennedy@paradise.net.nz
web: peter.kennedy@havelocknorth.govt.nz